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BUILDING MATERIALS.

BUILDING MATERIALS

THEIR NATURE, PROPERTIES AND MANUFACTURE.

A TEXT-BOOK FOR STUDENTS AND OTHERS.

BY

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"STRESSES AND THRUSTS," "THE DRAINAGE OF TOWN AND COUNTRY HOUSES," "SURVEYING AND SURVEYING INSTRUMENTS," "THE PRINCIPLES OF ARCHITECTURAL PERSPECTIVE," ETC.

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G. T.

PREFACE.

FOR many years past I have had in contemplation the preparation of a book in which building materials should be described and their present methods of manufacture explained. As time went on, the need for such a book—a modern book at a moderate cost—was more and more forcibly brought home to me, owing to the extreme difficulty which my students found in obtaining reliable and recent information. In undertaking to prepare such a book I knew the task would be no light one, and it has proved even more arduous than I had anticipated. For more than eighteen months every moment which I could spare has been devoted to collecting and arranging notes, interviewing manufacturers, inspecting works, and to a lesser extent to actually writing the book which is now about to see the light. At one time the notes alone more than filled a large drawer made for double-elephant paper; while hundreds of letters and post-cards have been written for the purpose of obtaining at first-hand the information which is contained in the volume—often compressed into tabular form. Wherever possible, too, I have seen things for myself, visiting the slate quarries of North Wales, the stone quarries of Somerset, Gloucestershire and Rutlandshire, the iron and steel works of Middlesbrough, the terra-cotta works of Ruabon, Portland cement works at Greenhithe and near Leamington, and numerous brickfields and lime-kilns, and important manufacturing premises, in and around London.

Wherever I have visited, and however searching my enquiries have been, I have been received with the utmost

courtesy; everybody I have met has shown the utmost readiness to help me. Without particularising, which would be impossible where so many are concerned, I would here desire to express my thanks to all who have assisted me, from the manufacturers who have thrown large works open to my inspection, to the working "hand" who by a few quiet words has explained some point which was puzzling me at the moment.

I am greatly indebted, also, to those who have permitted me to quote from their writings or catalogues, many important points being in this way added to the book.

For my own part, I have striven to express myself clearly and without redundancy. At times it has been difficult to restrain a tendency to enlarge, and at others to know when and where to stop; and yet at others to decide what to illustrate and what to leave to verbal description only. My aim has been to include all information that possibly could be of value or interest to English users of building materials, and to exclude all else.

Personally I have learnt a great deal during the preparation of this book, and all that I have learnt I have endeavoured to express therein for the benefit of others; but fresh knowledge comes to me almost every day. The subject is by no means exhausted; in fact upon each separate branch of it whole volumes have been, and doubtless will continue to be, written. Those who wish to investigate more deeply should go to such specialised books; and all should do as I have tried to do—they should visit works and see things for themselves, and should make for themselves labelled collections of the principal materials used in building.

G. A. T. MIDDLETON.

LONDON,
January, 1905.

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ERRATA.

P. 21. Line 15. For "the mat" *read* "them at."

P. 64. Line 20. For "Serverezza" *read* "Serravezza."

P. 172. 5th line from bottom. For "Machine burnt" *read* "Machine made."

P. 182. Fig. 45 is upside down and reversed.

P. 276. In the first Table, under Cast Iron, for "No elasticity" *read* "Almost perfect elasticity."

P. 355. For "Carbolizing Coating" *read* "Carbonising Coating."

for washing away, or detrusion, and providing fresh seas for its deposit.

Sometimes these deposits contained in themselves a cementing material such as rendered them hard, and in other cases they were hardened by the extreme pressure exercised during subsequent bucklings, or by the heat then generated, or by a combination of these. Such rocks

BUILDING MATERIALS.

Chapter I.

GEOLOGICAL INTRODUCTION.

THE mineral wealth of Great Britain, and incidentally the amount and variety of the natural building materials found in the country, is mainly due to the fact that, in one district or another, almost every known geological formation occurs within workable distance of the surface. However the earth may have been originally formed, it is now generally accepted that for an incalculably long period it has been gradually cooling and simultaneously shrinking. While cooling a crust has formed upon the surface, but this crust is so thin in comparison to the whole mass that it has buckled like a deflated hollow rubber ball during the consequent shrinking. Thus hills were formed; and rain falling upon the hills washed away any soft material with which they were covered, depositing these in the greater depressions which contained the seas. Subsequent shrinkages of the earth caused subsequent bucklings, different from the first, depressing the former hills and raising the former sea levels, exposing fresh surfaces of soft material, for washing away, or detrusion, and providing fresh seas for its deposit.

Sometimes these deposits contained in themselves a cementing material such as rendered them hard, and in other cases they were hardened by the extreme pressure exercised during subsequent bucklings, or by the heat then generated, or by a combination of these. Such rocks

would resist subsequent detrusion, while generally retaining signs, by occurring in regular layers or strata, of their original aqueous origin, and would become more hard and compact as time went on and further pressure was exercised.

Thus, roughly speaking, it may be expected that the oldest rocks would be the hardest, the softer portions of the older deposits being continuously washed away to form fresh strata; and, with many exceptions and variations, this may be accepted as the rule.

The building up of the earth's surface to its present condition has probably been perfectly uniform and without intermission, but geologists have found it convenient to divide geological time into epochs corresponding with breaks in the continuity of their earlier discoveries. Five great divisions are recognised: Acute Primary, Primary, Secondary, Tertiary, and Post Tertiary. Each of these, except the Acute Primary, is again subdivided, in some cases with great minuteness, but it will suffice for present purposes to give only the table on the opposite page.

Of the materials mentioned in this list, the sandstones are of purely sedimentary origin, consisting of grains of quartz or sand washed down from earlier deposits and solidified either by deposit in a calm water highly charged with silica in such a form as to cement the silica (or sand) grains; or more often the accumulated heaps of sand, covered by great thicknesses of other rocks, have been slowly raised into dry land by gradual upheaval, and then penetrated by water holding the cementing material in solution. Iron also is generally present, and no doubt assists in the cementation, for when present it occurs as an extremely thin covering to the sand grains, to which it imparts any colour which the stone may have, the pure silica being white.

The independent sandstone rocks found lying upon the surface in some parts of the country, notably in Dorsetshire and Wiltshire, and known as Sarsen Stones, are the remains of beds of which only these lumps were ever converted into

TABLE OF GEOLOGICAL FORMATIONS IN WHICH BRITISH BUILDING MATERIALS OCCUR.

Formation.	Series.	Example of Material found in it.
Post Tertiary.	Recent	Sand.
	Pleistocene	Brick earths and Thames gravel.
Tertiary.	Pliocene	Suffolk brick earths.
	Miocene	Sands.
	Eocene	Pottery clay; Roman and Medina cement; brick earths.
Secondary.	Cretaceous — Upper	Chalk; Gault clay for bricks and cement.
	Cretaceous — Lower	Kentish rag.
	Jurassic — Oölitic — Upper ...	Purbeck marble; Portland stone.
	Jurassic — Oölitic — Lower ...	Bath stone.
	Jurassic — Liassic	Cleveland iron ore; Hydraulic lime.
	Triassic	Runcorn stone; Alabaster.
Primary.	Permian	Magnesian limestones and Dolomites; Staffordshire brick earths.
	Carboniferous — Coal Measures	Coal; Clay ironstone; York flag-stones; Fire-clays.
	Carboniferous — Mill-stone grit	Yorkshire grit stones; Dinas fire clay.
	Carboniferous — Carboniferous limestone	Derbyshire marble; zinc and lead ore; Hæmatite iron ore.
	Devonian	Cornish slates; Devonshire marble.
	Silurian	Westmorland slates.
	Cambrian	Welsh slates.
Acute Primary.	Fundamental Gneiss	Road metal.

solid rock. All else has been washed away, together with immediately underlying strata, and the blocks have thus been gradually lowered until they rest upon an entirely different, harder and earlier formation, which now forms the surface.

Slate also is originally of sedimentary origin, being formed of clay deposited in shallow water in thin layers. Subsequent buckling of the earth's surface, however, brought great pressure and accompanying heat to bear upon the soft clay, compressing it into a hard mass, obliterating all generally observable signs of the original stratification and substituting another at right angles to the direction of the pressure thus exercised, this artificial stratification being known as "slaty cleavage."

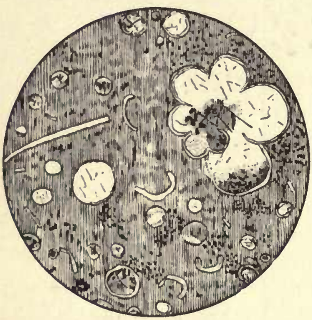


Fig. 1. Structure of Chalk (after Sorby). Magnified 100 diameters.

Many of the comparatively homogeneous limestones are sedimentary, especially such as contain clay or silica and were deposited in comparatively shallow water; but others are composed almost wholly of fossil shells and fish bones, and must have been formed very slowly in deep water, being compacted by the superincumbent weight of water. Such is chalk, whose absorbent power is so great that a cubic foot will hold a gallon of water without super-saturation. It is composed of most beautiful shells, microscopic in size, corresponding to the shells of minute organisms still living in abundance in oceanic waters (see Fig. 1). Others, even such hard, compact crystalline limestones as, taking a high polish and being ornamental, are called Marbles, are of coral origin, similar rock now being formed in the tropics, where recently formed coral is being so altered by water as to become a compact rock; while those

of the oölite class must have been formed from a limestone sand or coral detritus of very fine grain rolling about in a shallow water highly charged with carbonate of lime. Each small grain of limestone would thus become coated with more, each grain presently approximating to an onion in structure, and eventually the grains would adhere to one another and form a mass of stone with a structure like that of a fish's roe (see Fig. 2).

The exceedingly fine-grained dolomites and magnesian limestones, on the other hand, are probably chemically deposited rocks. Streams of water containing the salts of lime and magnesia *in solution* (as distinguished from mechanical washing) have emptied into salt lakes kept at their normal level by evaporation, and not by overflow along an outgoing stream. The natural result of the evaporation has been super-saturation of the lake water with the salts and the precipitation of the surplus as an impalpable powder. This has compacted into stone from its own power of adhesion and the weight of the water above it. Many of these stones contain mechanically deposited silica also.

Fig. 2. Microscopic Structure of Oölitic Limestone (after Sorby). Magnified 30 diameters.

The Italian limestone known as Travertin is similarly a chemical deposit of pure carbonate of lime in the lakes of the Campagna, which are fed by streams from hills of a cretaceous limestone.

True Oriental alabaster, a carbonate of lime, is of stalagmitic origin, having been the filling of cavernous hollows in limestone rocks by percolation of water containing carbonate of lime; while most of what is now called alabaster, a sulphate of lime, is another salt-lake deposit.

True marbles are, like slate, metamorphosed or changed rocks. Any limestone, on being heated to redness in such a position that the carbonic acid gas which it contains cannot escape, will on cooling become marble by crystallisation—much harder and more compact than before, and quite different in structure, but of the original chemical composition. Thus marble has been formed at almost all geological periods from previously existing limestones; and it is geologically dated according to the original deposit, which can be ascertained by sequence; and not by the time of metamorphosis, which is generally indeterminable (see Fig. 3).

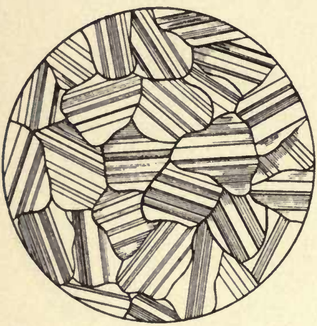


Fig. 3. Microscopic Structure of White Statuary Marble (after Geikie). Magnified 50 diameters.

Granites, it will be noticed, are not mentioned at all in the Table, for they are eruptive rocks, which have been formed at all geological periods. Sometimes when the crust of the earth has buckled, vents have occurred and the molten mass beneath the surface has found exit. If this has burst out, as in a volcanic eruption, it has become mixed with air, and has poured out as lava streams, or has formed pozzuolana or pumice—all chemically akin to granite. If, however, this molten mass, instead of bursting out, has cooled, its constituents have formed themselves into crystals while the whole has become a solid rock, and this rock is granite. Sometimes this occurs in large masses, and sometimes, as in the Auvergne district of France, as pillars of rock standing out above a plain—the solid rock cores of old volcanoes from which all the surrounding softer earth which formed the conical hills has been washed away.

Lava streams, on cooling, develop a remarkable columnar

structure, which is well displayed at the Giant's Causeway in Ireland, and at the Isle of Staffa in the Hebrides, this being due to shrinkage of the homogeneous mass resulting in vertical splitting. Such lava rocks are known as Basalt and Dolerite, the basalt being a compact rock whose component minerals are so intimately intermingled that they are separately indistinguishable to the eye, while the dolerite is coarser in texture though similar in composition, in which the intermingled minerals of which it is composed can be readily seen.

Chapter II.

INTRODUCTION: CHEMISTRY AND PHYSICS.

MATTER is capable under certain conditions of undergoing various changes, all of which are distinguished either as *chemical* or *physical*. If water is mixed with fragments of limestone no alteration is noticed in the stone or the water, but if the lime is first burnt in a kiln and water is thrown upon it, a violent action is seen to take place in the mixture. It is obvious that some material change has taken place in the limestone, that is to say it no longer exists as limestone, but as something quite different. Wherever a substance is influenced in such a way as to produce something essentially different, a *chemical change* is said to have been brought about. Chemistry is the science which investigates the nature of such changes.

If water be heated, it commences after a while to boil and passes away in the form of steam, which when cooled again becomes liquid water. In this case the heating has simply had the effect of dividing the water up into very small particles, which on cooling have collected again in the form of drops. In this case no essential change has taken place in the water, that is to say it is still the same kind of substance, whether in the form of water or steam, but it has merely passed from the liquid state to the gaseous state and back again to the liquid state.

Whenever a change is brought about without affecting the composition of a substance so altered, a *physical change* is said to have occurred. It should be noted, too, that such properties as appearance, weight, hardness, resistance to tension and compression, etc., are termed *physical* properties.

THE CONSTITUTION OF MATTER.—*Molecules.*—To the mind of a chemist or physicist no substance is absolutely homogeneous, but consists of a vast aggregation of minute particles called *molecules.* These molecules in any particular substance are all alike; thus in lead the molecules are all of one kind, while in water the molecules are all of another kind, the properties belonging to the substance being the properties belonging to the molecules in each case.

A fragment of ice, a drop of water, or a volume of steam, each consists of an aggregation of molecules. What constitutes the difference of state is explained as follows: When the ice is heated the spaces between the molecules become enlarged, that is to say the molecules are thrust further apart so that they are freer to move. Thus the solid ice becomes liquid water. If now the water is still further heated the molecules become thrust still further apart and the substance assumes the gaseous condition. In the process of cooling the molecules are drawn closer together again.

In all substances the molecules exert a force upon one another, which force may be either repellent or attractive. When the attractive forces are in the ascendency the molecules are drawn tightly together and the substance appears in the solid state. Where the repellent forces get the upper hand of the attractive forces the substance appears in the gaseous state. A liquid may be regarded as a substance in which the attractive and repellent forces are just counterbalancing one another.

Atoms.—To the chemist's mind the molecule is not an indivisible particle of matter, but is itself composed of smaller particles held together by the action of a force known as *chemical affinity* or *chemical attraction.*

There is a striking analogy between the appearance of a molecule and that of a solar system, the atoms forming the molecule revolving about one another independently of the motion of the whole molecule, just as in a solar system the various members perform certain movements relatively to

one another but independently of the motion of the whole system along its prescribed orbit.

We can now conceive more clearly the difference between a chemical and a physical change. If a molecule is so

LIST OF THE CHEMICAL ELEMENTS WHICH MOST FREQUENTLY OCCUR IN BUILDING MATERIALS.

Element.	Symbol.	Atomic Weight, neglecting decimals.
Non-Metallic.		
Hydrogen	H	1
Carbon	C	12
Nitrogen	N	14
Oxygen	O	16
Silicon	Si	28
Phosphorus	P	31
Sulphur	S	32
Chlorine	Cl	35
Arsenic	As	75
Metallic.		
Sodium	Na	23
Magnesium	Mg	24
Aluminium	Al	27
Potassium	K	39
Calcium	Ca	40
Manganese	Mn	55
Iron	Fe	56
Nickel	Ni	59
Cobalt	Co	59
Copper	Cu	63
Zinc	Zn	65
Silver	Ag	108
Cadmium	Cd	112
Tin	Sn	118
Barium	Ba	137
Lead...	Pb	207
Bismuth	Bi	207

acted upon as to overcome the force of chemical affinity, that is so as to expel one or more of the atoms bound together by the action of this force, then a chemical change has been brought about. Thus with the limestone already

mentioned, the molecule of which consists of one atom of the metal calcium, one atom of carbon, and three atoms of oxygen, the heat generated in the kiln by the combustion of coal partly overcomes the affinity of these atoms and splits up each molecule into two different molecules—one of lime, containing one atom of calcium and one of oxygen, the other of invisible gas (carbon dioxide), consisting of one atom of carbon and two of oxygen.

A change would be called physical when the motion of the molecules is affected without affecting the arrangement of the atoms in the molecules. Thus if we place a piece of iron in a fire it soon glows with a red colour, but it is still iron, a physical change only having taken place.

ELEMENTS AND COMPOUNDS.—In the molecules of certain substances the atoms are all of one kind. Such substances are distinguished as *elements*. There are about 70 elements known to the scientific world, but new ones are discovered from time to time. A list of those which most frequently occur in building materials is printed on p. 10. Other substances are built up of molecules in which the atoms are of different kinds. Such substances are termed *chemical compounds*.

DALTON'S ATOMIC THEORY.—The theory that matter was composed of atoms, too small to be seen and in a state of continual motion, was propounded by the Greek philosophers Leucippus and Democritus (460—400 B.C.). This conception, however, was not gained by experimental proof, but was purely a matter of opinion which happened to be coincident with truth. It was not until the beginning of the nineteenth century that John Dalton, a Manchester schoolmaster, in order to account for the then recently discovered fact that all *compounds have invariably the same composition*, revived the theory. An account of his theory was published in his "New Principles of Chemistry" in the year 1808.

This theory may be expressed as follows:—

(1.) Matter is capable of division up to a certain point only, the ultimate particles being called atoms. In the

case of the same element the atoms are all alike, but in the case of different substances the atoms differ in weight and chemical properties.

(2.) When chemical combination takes place between two substances the combination actually takes place between the atoms.

SYMBOLS.—It has been universally agreed by chemists to denote the atoms of the various elementary forms of matter by means of symbols. These symbols are given in the second column of the list on p. 10.

In many cases the initial letter of the name of the element is used to denote its atom—*e.g.*, Hydrogen, H ; Sulphur, S : but where the initial letters of two elements are the same, then the initial letter and another letter most prominently heard in pronouncing the name is used to denote one of them—*e.g.*, Chlorine, Cl ; Magnesium, Mg. In other cases the prominent letters heard in pronouncing the Latin name of the element is used—*e.g.*, Pb (Plumbum), lead; Cu (Cuprum), copper.

It must be strictly understood that it is not correct to say "two tons of Fe" when "two tons of iron" is meant, for the symbol Fe stands for *one atom* of iron, and is not merely a shorthand sign for iron.

ATOMIC WEIGHTS.—It is found, also, that the different kinds of atoms have different weights. Of course, it is impossible to determine the absolute weight of so small a particle as a separate atom, but it is possible to find the weight of the atoms relatively to some standard atom.* This standard is the hydrogen atom, hydrogen being the lightest substance known. The third column of the list (p. 10) gives the approximate relative weights of the atoms.

FORMULÆ.—It has been mentioned already that a molecule is regarded as a system of atoms. The question that naturally arises is—How many atoms are there in a molecule? The number of atoms which compose the

* The determination of atomic weight is in many cases a very complex matter, and is a subject which scarcely comes within the province of a book on building materials.

various elementary molecules is not the same in all cases. The molecules of sodium, potassium, zinc, cadmium, and mercury contain only one atom, the terms molecule and atom being in these cases synonymous, and such molecules as these being termed *mon-atomic* molecules. In the case of hydrogen, bromine, chlorine, oxygen, and nitrogen the molecules are composed of two atoms, and are termed *di-atomic*. The molecules of ozone contain three atoms, and are therefore termed *tri-atomic*, while arsenic and phosphorus contain four atoms to the molecule, and are therefore said to form *tetra-atomic* molecules.

The terms mon-atomic, di-atomic, etc., are only applied to elementary molecules. Compound molecules may be formed of practically any number of atoms.

According to the chemical system of notation the molecules of elementary substances are represented by the symbol for its atom followed by a small numeral—*e.g.*, the hydrogen molecule is represented thus: H_2. The molecules of ozone and phosphorus are respectively represented by O_3 and P_4. When it is desired to represent a molecule of a compound substance, the symbols for the component atoms are placed in immediate juxtaposition, and thus HCl represents the molecule of hydrochloric acid. If a molecule contains more than one atom of any particular element, the small numeral is used, as in the case of an element. Thus H_2O represents water, $K_2Cr_2O_7$ potassium bichromate.

Sometimes it is necessary to represent molecules which contain a group of elements acting as a single element. Such groups are placed between brackets with the numeral (if necessary) after it. Thus $(NH_4)_2SO_4$ represents ammonium sulphate. Such groups are called *compound radicals*.

There are a vast number of instances where simple molecules unite together to form more complex molecules. Thus, aluminium sulphate $Al_2(SO_4)_3$; potassium sulphate K_2SO_4 and twenty-four molecules of water $24\,H_2O$

combine together and form a molecule of a substance known as potassium alum, having the formulæ $Al_2(SO_4)_3$, K_2SO_4, $24\,H_2O$. Felspar forms a molecule of the same kind: $6\,SiO_2$, Al_2O_3, K_2O.

It should be carefully noted that since an atom is the smallest particle into which matter can be divided, it is impossible to have less than a whole atom of any element in a molecule. Such a formula as $Cu_{\frac{1}{2}}\,S_{\frac{1}{4}}$ would be absurd.

CHEMICAL EQUATIONS.—Chemistry, we have said, deals with a certain class of changes. It is therefore very desirable to have a system which represents these changes in a simple and comprehensive manner. For this purpose *chemical equations* are used.

Suppose iron filings and sulphur are mixed together in the proportion of their atomic weights and strongly heated; the two elements combine to form a yellowish-grey compound. In the action which has taken place, each molecule of iron has united with a molecule of sulphur to form a substance known as ferrous sulphide.

These facts are expressed thus:—

$$Fe + S = FeS \quad . \quad . \quad (1).$$

In the extraction of copper it is found necessary to treat the sulphide ore Cu_2S with a solution of a ferric salt—*e.g.*, Fe_2Cl_6, the cuprous sulphide reducing the ferric chloride with the formation of cuprous chloride and free sulphur. This change is expressed thus:—

$$2\,Cu_2S + Fe_2Cl_6 = FeCl_2 + 2\,Cu_2Cl_2 + 2\,S \quad . \quad (2).$$

If, again, ammonium cyanate is gently heated, the atoms in its molecule arrange themselves differently, so that an entirely new substance is formed with exactly the same atoms in its molecules. The action is expressed thus:—

$$(CN)O(NH_4) = (NH_2)_2CO \quad . \quad (3).$$

It should be noted that in the above three examples of chemical equations both sides balance—that is to say, there

is the same number of atoms on each side of the = sign. Equations must always balance, for *matter is indestructible.*

THREE TYPES OF CHEMICAL EQUATION.—All known instances of chemical action can be referred to one of three modes in which the rearrangement of the atoms can take place:—

(*a*) By the direct combination of two molecules to form a more complex molecule. Equation (1) is an example.

(*b*) By a mutual exchange of atoms in two molecules. See equation (2).

(*c*) By the rearrangement of the atoms in the molecule. See equation (3).

QUANTITATIVE SIGNIFICANCE OF CHEMICAL EQUATIONS.—Not only does an equation express the qualitative nature of a chemical change, but a quantitative meaning can also be attached to it. We have already seen that the weights of the elementary atoms have been found in relation to the weight of an atom of hydrogen. The symbol stands for one atom of an element. Now, from the list of elements (p. 10), we see that the atomic or relative weight of iron is 56, of sulphur 32; then in the equation (1) it is obvious that 56 parts by weight of iron combine with 32 parts by weight of sulphur, and form $(56+32)=88$ parts by weight of ferrous sulphide. If, therefore, we heated 56 tons of iron with 32 tons of sulphur, we should form 88 tons of ferrous sulphide.

The following question and solution will show the use of this quantitative notation:—

What weight of quicklime would be obtained by burning 5 tons of limestone? How much carbon dioxide would be driven off?

Solution:—

The equation of change is:

$$\begin{array}{ccccc} CaCO_3 & = & CaO & + & CO_2 \\ \text{Tons.} & & \text{Tons.} & & \text{Tons.} \\ (40 + 12 + 3 \times 16) & = & (40 + 16) & + & (12 + 2 \times 16) \\ 100 & = & 56 & + & 44. \end{array}$$

100 tons of limestone produce 56 tons of lime

$\therefore$ 5 " " " $\frac{56 \times 5}{100}$ tons of lime

$= 2$ tons 16 cwts.

Weight of carbon dioxide driven off $=$ 5 tons $-$ 2 tons 16 cwts.

$= 2$ tons 4 cwts.

DIVISION OF ELEMENTS.—It is found that certain properties are common to a large number of elements, and it is on account of these properties, which are chiefly physical in character, that the elements are divided into two classes, known as *metals* and *non-metals.* The metals are opaque, and their surfaces are capable, when smooth, of reflecting light to a high degree, giving them the appearance known as *metallic lustre.* They also conduct heat and electricity. The metals and non-metals are shown in the list on p. 10.

ACIDS AND ALKALIES.—With the exception of fluorine and bromine all elements combine with oxygen and form compounds called *oxides.*

The oxides of the alkali metals (soda, Na_2O; potash, K_2O) readily combine with water, forming the *hydro-oxides* $NaOH$ and KOH; and those of the alkaline earths (lime, CaO; strontia, SrO; baryta, BaO) likewise form hydro-oxides $Ca(OH)_2$, $Sr(OH)_2$, and $Ba(OH)_2$. They are all readily soluble in water, and the solution has a soapy feeling, and the property of imparting a blue colour to litmus, a vegetable colouring matter. A substance which turns litmus blue is called an *alkali* and is said to have an *alkaline reaction* to litmus. Such oxides are called *salt-forming* oxides, or *basic oxides*, or simply bases.

On the other hand, oxides of the non-metallic elements (*e.g.*, SO_2, SO_3, CO_2, N_2O_5, and P_2O_5) combine with water to form compounds called acids, which are often corrosive, possess a sour taste, and turn litmus red.

SALTS.—When chemical action takes place between an acid and a base a class of compounds is formed called salts—*e.g.*:

$$\begin{array}{llll} \text{Base} + & \text{Acid} = & \text{Salt} & + \text{Water} \\ ZnO + & H_2SO_4 = & ZnSO_4 & + H_2O \\ Fe_2O_3 + & 3\,H_2SO_4 = & Fe_2(SO_4)_3 & + 3\,H_2O \end{array}$$

As having a very important bearing upon many of the materials to be considered later in this book, the following note on the nature of solutions—particularly of solid solutions—is extracted from a Paper by Mr. Clifford Richardson, of the New York Testing Laboratory:—

"Solutions may be defined as the merging of two or more substances in one another in such a way that it is impossible to recognise them by any physical means. In this respect they differ from the elements and definite chemical compounds. The elements cannot be or have not been differentiated by any chemical or physical means into other substances. Definite chemical compounds can be differentiated by chemical means into their constituent elements, but at the same time are always composed of these elements in a definite mathematical ratio, involving only whole numbers and depending upon the combining weight of each element.

"Mixtures of gases, gases dissolved in liquids, liquids which are mixed together and salts dissolved in liquids, are types of solutions. In the preceding paragraph mention has been made of solid solutions. We owe our conception of such solutions to Van't Hoff, a Dutch chemist, who, in 1890, having observed some abnormal features in the behaviour of certain solutions of solids in liquids when they were frozen, was led to believe that the solid which separates on freezing is not the pure solvent, but a mixture of the solid solvent and the dissolved substance forming a solid solution. Investigations have proved that the conception was justified. Roozeboom has shown from a study of mixtures of fused salts that, on cooling, solid solutions are often formed,

especially if the salts have the same crystalline form and habit.

"The constitution of our igneous rocks may best be explained by considering them as solid solutions, which, when the original liquid magma, from which they are derived, is cooled to a temperature at which freezing sets in, are formed by the crystallization of such mineral species as the constitution of the magma may permit, and which we recognise as quartz, mica, felspar, etc., the composition of which, while in approximately definite proportions, is more or less modified by the substances which they may retain in solution.

"The structure of alloys has also been most satisfactorily explained by considering that different metals are soluble in each other in different proportions under different states of concentration and at different temperatures; that of steel has been especially thoroughly worked out in the same way, and it has been shown that it consists of a solid solution of carbon in pure iron, while that of cast iron is explained by the fact that the amount of carbon soluble in the molten iron is so great that a portion separates out, as graphite, on cooling.

"Another type of solid solution is glass. In this material we have a solid solution of silica, lime and alkalies, in indefinite proportions, in which none of the constituents can be detected, and out of which nothing separates on freezing. This is regarded as a homogeneous solid solution, and corresponds closely to a homogeneous liquid solution.

"In some mixtures of fused salts and in some of the alloys we have heterogeneous solid solutions, as more than one solid solution may separate on freezing. Such a separation is due to what is known as selective freezing. This is well illustrated by the freezing of a solution of salt in water. That portion of the solvent which becomes solid first contains less salt than anything subsequently separated. If we take a 15 per cent. solution of salt in water as an example, as has been done by Howe in his excellent book

entitled 'Iron, Steel and other Alloys,' to which the reader is referred for an exhaustive explanation of the theory of solid solutions, and to which the writer is much indebted, it will be found that the solid matter that first freezes out is nearly pure water, and that there is a corresponding increase in the concentration of the mother liquor. The solid which subsequently separates will contain progressively more and more salt in solid solution in the ice, and there will be a progressive fall in the freezing point of this liquid, until when the temperature has reached minus 22 degrees C. and the proportion of salt in the mother liquor is 23·6 per cent., further concentration will not occur, and the two elements, water and salt, solidify without selection and form what is called an eutectic. The freezing point remains constant at 22 degrees C. until the entire material is solid. The solid originating in this way is a mixed mass of crystals of water and of salt inter-stratified, the salt forming 23·6 per cent. of it and ice 76·4 per cent. The same result would happen with a 20 per cent. solution of salt, the selective freezing going on until the concentration of 23·6 per cent. had been obtained and eutectic ratio had been reached. If the original solution contained 23·6 per cent. of salt it would not freeze until a temperature of minus 22 degrees C. had been reached, and then it would all become one uniformly mixed mass of the solid known as the eutectic. If the percentage of salt is greater than the eutectic ratio, 23·6 per cent., then the material which first freezes will be salt containing some water in solution, and the concentration in relation to salt would be reduced until the eutectic ratio is reached. That is to say, the composition of the eutectic is constant, no matter what the initial ratio is between the solvent and that which it dissolves.

"Again, many alloys are quite parallel in their constitution to that of the solid salt water series. Tin and lead form an eutectic constituting 31 per cent. of tin and 69 per cent. of lead of constant freezing point. Any tin-lead alloy of other than the eutectic proportion will consist

C 2

of lead with tin in solution and the eutectic, or tin with some lead in solution and the eutectic, in accordance with whether the lead or tin are in excess over the eutectic ratio.

"In some cases, however, where metals or salts are not mutually soluble in the solid state, unselective freezing may take place, that is to say, the elements of the fused solution may solidify separately, and this may be regarded as an eutectiferous mixture.

"The term eutectic means well melting, because the eutectic is usually the material which freezes out at the lowest temperature, no matter what the proportions may be of which the mixture may happen to consist.

"Two salts which crystallise in the same form may separate from aqueous solutions in such a crystalline form containing more or less of both substances, depending upon the concentration, and in the same way a crystal consisting entirely of one salt may be built up with another by immersing it in a solution of a so-called isomorphous salt of proper concentration, that is to say, of a salt which crystallises in the same form. These crystals are known as isomorphous mixtures, or mixed crystals.

"Exceptionally a substance which crystallises in a different form from another may assume the form of the latter, and crystallise with it as a so-called isodimorphous mixture or solid solution. The salt which has changed its form must of course, be under a certain tension in such a solution. Such a state of affairs will be found to be the case in a Portland cement clinker, and an example of such an isodimorphous mixture among simple well-known salts will be instructive. The orthorhombic sulphate of magnesia, $MgSO_4$, $7\,H_2O$, for instance, can take up and hold in solution in the form of orthorhombic crystals as much as 18·78 per cent. of the monoclinic ferrous sulphate, Fe_2SO_4, $7\,H_2O$, while the iron salt can take up 46·00 per cent. of the magnesia sulphate, and hold it in solution in the monoclinic form. Between these limits we find both forms of solid solutions or crystals present. The relation of the

isotropic aluminates of lime to the anisotropic silicates will be found to be, in Portland cement clinker, similar to that which has been described.

"The relation of materials to each other which are not soluble or mixable with each other in all proportions may be also illustrated by mixtures of ether and water. In such mixtures, if they are shaken, and the amount of ether present is not greater than what the water can dissolve, a homogeneous solution is formed. As soon as the proportion of ether reaches a point where it will not dissolve on shaking, an emulsion will form, and this will continue to be the case with the increase in the proportion of ether until the latter reaches an amount where it can dissolve the water present. If it were possible to cool ether-water mixtures so rapidly as to solidify the mat once, we should find, for certain concentrations where the ether was only slightly in excess of what could dissolve, a solid solution of water and ether and an emulsion of water and ether corresponding in structure to an eutectic; but here the eutectic would not consist of separate particles of ether and water, but of separate particles of ether saturated with water and water saturated with ether. This is a structure which is met with in Portland cement clinker. Whether it is an eutectic or not is unimportant. It is the structure itself which is illustrative of what takes place when the components of the mixture are not soluble in each other in all proportions. In Portland cement clinker of certain concentration similar emulsions are found.

"Steel is a solution of carbon in pure iron. Carbon dissolves in the molten iron to a very considerable extent, and remains in solution as long as the metal is molten. If cooling and freezing takes place, the structure of the solid metal will be found to depend upon the proportion of carbon which was dissolved in the original iron, and the temperature at which it was cooled. If carbon amounts to but a few hundredths of 1 per cent., the solid metal will be wrought iron; if it does not exceed that amount which will

remain in solution in iron after cooling it is steel; if the carbon is greater than this some of it will separate as graphite, and the solid metal will be cast iron.

"The structure of the metal in the solid state under these different conditions may be determined with the microscope, but, of course, not in thin sections, as in the case of clinker, but by the examination of polished surfaces, which have been etched in some appropriate way.

"When molten iron containing carbon in solution, in amount insufficient to cause a separation of graphite on cooling, is rapidly cooled from a very high temperature, the solid metal will be found to have definite properties, depending on the percentage of carbon present, the lower percentages furnishing mild steel, the higher tool steel, with a structure which is so definite that it has been named austenite. It will be also found that when the steel in this condition is reheated, as in tempering, the austenite structure is lost, the metal being transformed into a material of quite a different structure, with resulting changes in its physical properties."

Chapter III.

STONES: PRACTICAL CLASSIFICATION AND GENERAL DISTINCTIONS.

THE classification of stones as BASALTS, GRANITE, SLATES, MARBLES, LIMESTONES, and SANDSTONES, though in some respects unscientific, is so convenient and so generally accepted and suited to practical needs, that it must perforce be adopted by all users of stone. The distinctions between the classes are well marked, and such as are discernible in most cases at sight, the occasional practical inclusion in one class of a stone which scientifically belongs to another being due to this fact—that in practice a stone is classed as that which it appears to be rather than as that which scientific investigation proves it to be.

The term BASALT, for instance, is made to include all black, heavy, homogeneous, or nearly homogeneous, stones, like the *Trap* or *Greenstone*. The true BASALT is an *Augitic* stone, named after the mineral *Augite* or *Pyroxene*, of which, with *Labradorite Felspar* (a silicate of alumina and lime), it is composed—*Augite* having magnesia for its base, and being of a dark or black colour. There is much of it in the British Islands, including the whole county of Antrim, several islands of the Hebrides, and parts of Wales, Cumberland, Shropshire, and Staffordshire; but it is so difficult to quarry and hard to work that it is little used, save locally as road metal. BASALT was, however, largely employed by the Egyptians for sculpture, there being several specimens of its use for this purpose in the British Museum; while in the volcanic district round Naples it has at all times been much used for paving purposes, as in the Via Sacra and the Appian Way at Rome.

Of the Diosites, or Greenstones, which are, correctly

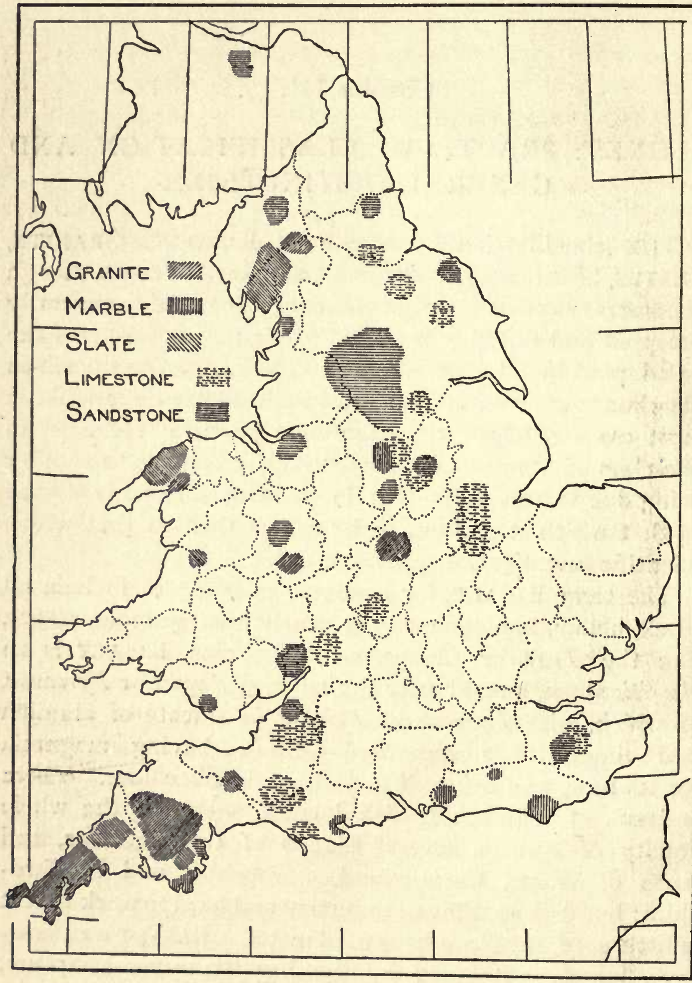


Fig. 4. Lithological Map of England.

speaking, not BASALTS, but Hornblendic stones, the most used in England are the Penmaenmawr stone of North

Wales, and the Bardon Hill stone of Leicestershire—both excellent paving stones; while the Napoleonite of Corsica is a handsome ornamental stone. Of the same hornblendic class, too, is the Rowley Rag of Staffordshire, which in addition to its use for paving purposes, has been melted and cast into ornamental articles.

GRANITES comprise all stones of independent crystals of differing materials, which are so intimately connected as to form a homogeneous whole, and include most of the felspathic and hornblendic stones. All true granites contain felspar and quartz, and the ordinary typical granite consists of felspar, quartz, and mica, while many contain hornblende also.

Of these constituents, the felspar is generally of that description known as Orthoclase, which is a silicate of alumina and potash, though the Labradorite felspar is also found. Felspar varies in colour, being sometimes white, sometimes grey, sometimes pink, and sometimes a deep rich red, and the colour of the granite, of which it forms a large part, varies accordingly.

The quartz crystals also vary in tint, though they are frequently white. They are almost pure oxide of silicon (SiO_2), otherwise known as silica; and it is found that they contain minute cells partly filled with water. The grains of felspar and mica are partly embedded in the quartz grains, and hence it is concluded that the quartz was the last to solidify.

The mica occurs as small flakes of dark colour, which flash as they catch the light. It is a source of weakness, as it is liable to decay.

Hornblende, otherwise known as Amphibole, is a silicate of magnesia and lime, with iron and manganese. It is a very tough mineral, of a dark green or black colour, and frequently occurs in granites in small distinct crystals. Granites which contain hornblende in place of or in addition to mica, are called Hornblendic or Syenitic granites, while other stones which contain felspar and

hornblende alone, without either quartz or mica, are not granites at all, scientifically speaking, but Syenites, though in practice they are included among the granites.

The crushing resistance of an ordinary granite varies from 5 to 12 tons per square inch, as tested on small cubes, and its weight from 160 to 190 lbs. per cubic foot.

The principal granite districts in Great Britain are the North of Scotland, a great part of Ireland, Cornwall and Devonshire, Leicestershire, and the Channel Islands (see map), while much is also imported from Scandinavia and Russia.

Under the term GRANITE are commonly included other igneous rocks, little used for building purposes, such as the Porphyries, Elvan (of fine grain and free from mica), and Gneiss, which is constituted like granite, but has the mica more in layers, along which it splits easily, coming out in slabs from a few inches to a foot in thickness.

True SLATES are argillaceous in composition—that is, they are composed of clay (silicate of alumina) and little else. The chemical elements of all clay, shales and slates are aluminium, silicon and oxygen, and the origin of all alike is to be found in the natural production of Kaolin, a pure white clay, by the decomposition of the felspar of felspathic rocks such as granites. This is washed into streams and rivers and so is conveyed to the sea, where, consisting of matter in an extremely fine state of division, it is carried further from the shore than the other ingredients of the original granite, and so is deposited separately, forming a clay bed. This forms material for newer clays, and so on; while clay beds which have long been subjected to vertical pressure have been compacted into shales and mudstones, and when these again are subjected to great lateral pressure and high temperatures they have been changed into the hard and strong material known as slate. Owing to the extremely high temperature at which the change takes place, slate, like all other metamorphic and igneous rocks, contains no organic remains.

It is practically non-absorbent, and as it can be split into exceedingly thin parallel layers of considerable size, it is a most valuable roofing material.

The crushing resistance of slate varies from 6 to as much as 14 tons per square inch, and its weight from 165 to 180 lbs. per cubic foot, while its transverse strength is greater than that of any other stone.

True slates are found in large quantities in North Wales and in Westmorland and Lancashire, and to a smaller extent in the south-west and south of Ireland, in Cornwall, and in the south-west of Scotland (see map).

Many other stones, both sandstones and limestones, which naturally occur in thin enough layers to be used for roofing purposes, are locally known as "slates," or sometimes as "slate-stones," or "tile-stones." These, however, split along their planes of bedding, and not along planes of metamorphic cleavage, and so are not true slates, having, in fact, each the characteristics of the class of stone to which it belongs.

Colyweston "slates," for instance, found in Rutlandshire, near Stamford, though used as roof coverings, are really limestone of a dark grey colour. The stone is obtained in the form of a block, or slate log, showing no sign of lamination. The logs are quarried in the summer and exposed to the weather through the winter, being watered daily except when hard frozen. If the winter be one of successive frosts and thaws, the block splits into thin slabs, while continuous frost with few alternations will produce thick slabs only, the splitting being done entirely by the weather, and the "slates" being ready for use when the spring arrives.

Stone slabs for roofing purposes are also obtained in Somersetshire, but they are thicker and heavier than those from Colyweston. All such, however, are more absorbent than true slates, and require strong roof timbers to carry them, while they foster lichen growth; but their colour is pleasing, and some architects use them to a considerable extent.

The term MARBLE has come to include in practice not only marbles proper, but all limestones and even some other stones which are capable of being highly polished, and which then superficially look like marbles. True marbles are composed of practically pure carbonate of lime ($CaCO_3$) in a highly crystalline form, resembling lump sugar in structure. This resemblance is so strongly marked in the white that it has been given the name of "saccharine marble." The white marble has been metamorphosed from pure white limestones, while the coloured marbles derive their colour from impurities, mostly oxide of iron, in the original limestones from which they have been changed, the colour having run into beautiful veins and markings during metamorphosis. Almost all colours are represented, and all combinations of colour.

The crushing resistance of marble is about equal to that of granite, while its weight varies little from 170 lbs. per cubic foot.

Like granite and slate it is also an excellent weathering stone, and can be obtained in large blocks; though it does not, as a rule, retain its polish for any length of time if exposed to the weather. The combination in the same stone of strength, size of block and beauty of colour and texture, renders marble one of the most valuable of building materials.

White marbles are imported from Greece, Italy, and Norway, yellow marble from Italy, and veined marbles from Portugal and the Pyrenees; while Great Britain produces marble of many delicate tints in Devonshire and Cornwall, and rich black and red marbles in the South of Ireland.

Of other stones generally known as marbles the most valuable are the Green Serpentines, especially the monolithic Verde Antico from Larissa, in Turkey, and the Connemara marble from Ireland. These are metamorphic igneous rocks, produced by the alteration under heat of igneous rocks rich in olivine, which contains some 84 per cent. of

silicate of magnesia. This is frequently found intermingled with carbonate of lime formed by water percolation, and the result is a stone having a beautiful mottled surface. Though heavy and capable of carrying heavy loads, it is soft and easy to work, but it weathers badly, and so cannot be used externally with success. Lithologically, serpentines are Paleose stones, the mineral talc, which consists of silicate of magnesia and occurs in other forms as French chalk, steatite and asbestos, being its basis.

ALABASTERS are also commonly and wrongly classed among the marbles. The true Oriental Alabaster, obtained from quarries in Egypt, Assyria and Algeria, is a beautiful translucent and nearly white limestone, often now erroneously called onyx marble, whose circular markings indicate its stalagmitic origin. It is difficult to obtain, and is replaced in general use by the softer sulphate of lime, also known as alabaster, the two being superficially similar. This is found in considerable quantities near Paris, and in England in Derbyshire, Cheshire, Westmorland and Nottinghamshire; while recently a sulphate alabaster has been imported from Mexico for ornamental use under the name of Mexican onyx. Alabaster should only be employed internally and for ornamental purposes.

Derbyshire, Dorsetshire and Sussex produce formaniferal and encrinital compact limestones which take a good polish, and, owing to the fossils they contain, are beautifully marked. The polish, however, is not long retained on exposure to weather or wear, and so the ornamental use of these stones is restricted to certain internal positions only. They, also, are erroneously called marbles.

The term LIMESTONE, which properly includes the true marbles, is in practice restricted in its use to such stones, composed mainly of carbonate of lime, as are of so open a texture as to prevent their taking a polish. Even so, a wide range is covered, and many sub-divisions are possible. In physical structure alone there are wide divergences, ranging through all grades from the loosely compacted

chalk, which consists of the shells of minute formaniferæ, to the homogeneous Kentish Rag, the oölites occupying a middle position.

Of these, chalk occurs in Kent, Surrey, Sussex and Hampshire, and the Kentish Rag in Kent, while the oölites, which contain many of the best English building stones, extend over many counties, occurring principally in Dorsetshire, Wiltshire, Somersetshire, and Lincolnshire.

None are of very great weight or strength, the oölites weighing from 125 to 145 lbs. per foot cube, and having a crushing resistance of from ½ ton to 2 tons per square inch.

Oölitic stone as a rule is easy, and consequently inexpensive, to quarry and work, and is therefore known as a "freestone," while it possesses uniformity of colour (generally a light cream or brown), comes to a good surface, and weathers satisfactorily. Of sedimentary origin, it lies in beds, often of considerable thickness, though the "bedding" is still visible in the blocks. Sometimes this is shown by the position of fossil shells, which always lie flat on the beds, and sometimes by markings which, if of clay, are sources of weakness. Other markings, however, frequently traverse the beds, and are due to the vertical percolation of water through fissures; and these are not to be mistaken for bedding marks. Frequently the effect has been for the water to convey carbonate of lime to a fissure, which from being a source of weakness has become a source of strength on being filled with a crystalline substance; and in other cases a similar result has been achieved by percolation of silica, though silica veinings of this sort render a stone comparatively hard to work.

Lias Limestones—which, practically speaking, do not necessarily occur only in the lias formations — are such as include a considerable proportion of clay in their composition. They occur generally in thin beds only, and are more useful for street pavings than for building purposes, though they look well as "shoddies"—*i.e.*, rough ashlar facing blocks—with freestone dressings, on account of the

contrast of colour, the lias stones being generally of a dull and somewhat deep blue. This decorative use in contrast is noticeable in Glastonbury Abbey, in which the bases and bands are in several instances of lias, which has withstood some centuries of exposure admirably. Such stone occurs in Somersetshire, in South Wales, and near Rugby.

The Dolomites or Magnesian Limestones are also exceedingly important impure limestones. While magnesian limestones vary greatly in composition, the true dolomite is of a peculiar granular and crystalline structure, and is known to mineralogists as Bitter-spar, consisting of 54 parts of carbonate of lime to 46 parts of carbonate of magnesia in indivisible crystals. As a rule a dolomite is fine of grain, and uniform in colour and texture, moderately easy to work, and an excellent weathering stone. The weight is about 140 lbs. per cubic foot, and the crushing resistance from 3 to 4 tons per square inch. Such stones are found in Derbyshire, Nottinghamshire and Yorkshire. Some of them contain a considerable proportion of silica in the form of sand grains, and so are, perhaps more properly, classed among the sandstones by many writers.

The SANDSTONES include all stones whose grains are composed of silica (SiO_2). This mineral, the most abundant in Nature, assumes various forms, in some of which it is known as rock crystal, flint, chalcedony, agate, and amethyst, and constitutes not only the sands of the sea shore and the desert and the pebbles of shingle beaches, but the framework of many tropical sponges. This silica, or quartz as it is also called, being practically insoluble and of great hardness, endures when associated minerals are dissolved, decomposed, or reduced to impalpable dust. Thus the sand of which sandstones are composed has been derived either from quartzose igneous rocks such as granite, from the quartz veins of the older sedimentary rocks, from flints (which occur in chalk as lumps of silica deposited by water percolation in hollows originally formed by sponges in the chalk), and from the destruction of older

sandstones and beds of sand. The grains consequently vary much both in size and angularity, some sandstones being composed of grains both larger and angular, while others have very small and rounded grains, worn down to their present condition by long-continued rubbing by the action of moving water ; and all degrees between these two extremes are met with.

Some tropical sandstones, notably that of which the island of Bermuda is composed, consist entirely of microscopical diatoms, or the siliceous framework of minute marine organisms, of marvellously beautiful forms.

It is thus evident that the terms hard and soft, as applied to a sandstone, have no reference to the material of which the grains are composed, but only to the stone as a coherent mass, and so depend upon the character and amount of the cementing material. This varies also. It may, like the grains, be of silica, in which case the resulting stone is white and may be very hard ; or it may be of peroxide of iron (Fe_3O_4), familiarly known as rust, forming a thin red coating to the grains, and giving a red, brown or yellow colour to the stone, which may be very soft or very hard ; or it may be of clay, or of carbonate of lime ; or it may be a combination of two or more of these substances.

The sandstone deposits in Great Britain are extensive and valuable. The best are found in the Carboniferous series, in Yorkshire (near Bradford and Halifax), near Newcastle-on-Tyne, at Bristol, in the Forest of Dean, in South Wales, in mid-Scotland (near Edinburgh), and in the west of Ireland (co. Clare). The Trias yields the sandstones, mostly red, of Warwickshire, Cheshire and Lancashire, while a fine-grained pink sandstone is quarried from the Permian of Westmorland, and yellow and brown sandstones of comparatively little value are found in the Cretaceous formation of Kent and Surrey.

The weight of sandstone varies from 110 to 165 lbs. per cubic foot, and its crushing resistance from 2 to 4 tons per square inch.

Chapter IV.

STONE: ITS DURABILITY, SELECTION AND PRESERVATION—NOTES FOR USERS.

To all stone users the selection of the most suitable stone for the immediate purpose of the moment is a matter of supreme importance. That the information needed may always be at hand when required, it is well to keep a cabinet of labelled specimens, each label containing not only the generic name of the stone, but a brief record of its principal characteristics, the name and address of the quarry owner, the locality of the quarry, facilities for transport, and the price of the stone on rail or ship. Such a collection may take years to acquire, but its possession will often prove invaluable. There is scarcely a stone produced that is not frequently specified to be used in a position for which it is entirely unsuited, while the same stone might in another position, and for another purpose, be the best which could be utilised. Such improper specifying leads either to substitution or dissatisfaction, and could generally be prevented by the possession of an accurately-labelled sample, which a quarry owner will generally supply if there is a genuine likelihood of the stone being used.

Colour, in particular, is a point upon which actual inspection is infinitely more valuable than description, as in all colours the various shades are innumerable. Even samples often fail here, however, for many stones vary in tint not only between different beds of the same quarry, but even in different parts of the same block. Thus if strict uniformity is required it should be ascertained in advance whether it be obtainable.

Ornamental Markings, as in the veined and the

fossiliferous stones, stand in this respect upon the same footing as colour; and in the case of some of the English marbles even the quarrymen do not know till it is cut what will be the colour or the marking of the next block they bring out. In other cases the markings are quite different according to the plane along which the stone is cut, some stones, like the Greek Cippolino marble, being exceedingly beautiful along some planes and quite dull and lifeless along others; while the fossiliferous stones often show circular markings if the fossils are cut directly across and irregular or rectangular markings if they are cut longitudinally.

TEXTURE depends not only on the size of the grains of which a stone is built up, but on their character and the homogeneity of the mass, and is frequently of considerable importance. Most of the very hard stones, like the granites, marbles, and compact limestones, can be brought to a smooth surface, and in that condition be left plain or be highly polished, the latter being the more usual and displaying to perfection their marking and colouring. Granite, however, may be left with a roughly chiselled or even a hammer dressed surface, when its coarse and angular grain gives an effect of great solidity and strength. A somewhat similar effect can be conveyed by the use of the coarser sandstones, but it is missing with the coarse limestones, which suggest crumbling weakness if left rough, through the roundness of the oölite grains or the fragmentary stratification of the shells which they contain. Hard smooth limestones, however, like the lias, look strong when hammer dressed, exposing smooth chipped faces separated by sharp arrises; while smooth rubbed surfaces can be produced on the fine-grained sandstones and limestones alike.

HARDNESS is one of the qualities in a stone which most considerably affects its cost in use; for it is generally not so much the raw material which varies in price, as the value of the labour which has to be spent in working it. Thus

where economy is a principal object for consideration, the softest stone which will serve the purpose should be used. Elaborate carving, for instance, can be indulged in, where it is protected from the weather and from wear, without great expenditure if a very soft stone be used; while it would very likely cost three times as much if executed in a sufficiently hard stone to withstand exposure to weather or friction.

WEAR, however, in many positions demands something more than mere hardness to withstand it successfully. When used as stairs, landings, or pavements, many of the more compact stones become slippery, while others, like the lias limestones, wear into holes. An angular grit prevents slipperiness, and this is possessed as a rule by granite and the coarser sandstones. Those sandstones which, like the Yorkshire "flags," occur naturally in slabs of from 1½ ins. to 6 ins. in thickness with true surfaces, are much used for these purposes; but their layers of deposit are so clearly marked that if subject to heavy foot traffic they are liable to wear away in flakes, and the more homogeneously bedded sandstones, like that from Liscannor in co. Clare, the thicker Yorkshire stones, and the Forest of Dean and Pennant stones, are then to be preferred, especially for stairs.

STRENGTH in stone is not often a matter requiring great consideration, as under ordinary circumstances any stone is capable of bearing the slight load brought upon it; but where, as in vault groining, church pillars, columns, and girder bearings, great thrusts and loads are brought to bear upon small surfaces, strength becomes of supreme importance. In this matter care is necessary, for the results of tests upon small sample cubes are extremely deceptive, except in the case of the higher grade stones of uniform structure.

CORRECT BEDDING is, in the case of most of the laminated stones (*i.e.*, those deposited in layers or laminations) an absolute necessity. In ordinary walling, bearing

a vertical load only, the beds should lie horizontally. Were horizontal bedding attempted, however, with undercut mouldings, the undercut portion would flake off, as shown by dark lines in the illustration (Fig. 5), and so edge moulding is resorted to, with the bedding parallel to the vertical joints. Face-bedding, as it is called when the bedding lies vertically and parallel to the face of the wall, should never be used, as the surface tends to peel off. In the case of stones resisting heavy thrusts, the bedding must be at right angles to the thrust, as it is in this position that all stone is strongest to resist. A skilled mason can generally detect the bedding of a stone at sight, by noting that fossils lie flat on the bed, or by small bed markings; or if these fail he can "feel" the bed when he works the surface with his chisel. The inexperienced, however, are likely to be deceived by mere water veinings.

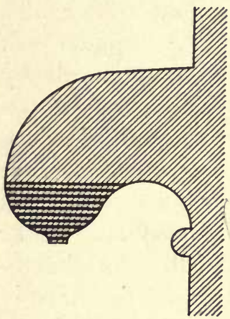


Fig. 5.

THE SIZE of slab and depth of bed obtainable are important factors in determining the selection of stones for many purposes, where large sizes are needed. Many otherwise excellent stones are obtainable only in comparatively thin beds. As a rule special inquiry upon this point is necessary, else much trouble and delay may result. Very few quarries, even those owned by wealthy firms and containing blocks of any size likely to be required, have the means of hoisting or of transporting stones weighing as much as 10 tons, and many limit their output to blocks of 100 cubic feet in bulk.

THE DURABILITY of a stone used externally seems to be a matter which can properly be determined by experience only. Where subject to the action of water and of marine insects, as in sea walls, weight and hardness are essential to durability, but in general building work this is not the case, many stones of comparatively light weight and open

structure being known to be excellent weathering stones. Water may penetrate into the pores of some stones, freeze, expand, and blow off fragments; but this is an infrequent occurrence, except with the very softest, which few would think of using. Similarly, in theory, limestones should not be able to resist the action of the acids contained in the air of all large towns; yet there are many nearly pure limestones which experience shows can be used with perfect safety in such places as London and Birmingham. Tests, whether mechanical, chemical, or microscopic, seem to be of little value. It is better not to trust to them, but to be guided by the results of the many experiments which men of previous generations have made, assuring yourself that you really are using practically the same stone as that in the building you trust to, and from the same quarry bed. Most quarries produce stone of several qualities, usually, though not invariably, the better weathering and harder stone underlying that of less value.

Even ABSORPTION is not an entirely reliable test of durability, and certainly not as between class and class of stone. Still, granite should not absorb more than ½ per cent. of its dry weight of water, slate not more than ¼ per cent., sandstone and dolomites not more than 5 per cent., and oölite limestones not more than 8 per cent. Walls built of absorbent stones are, it must be remembered, liable to be damp walls, especially if the stones be compact of structure as well as absorbent, and so of a nature which prevents their parting readily in fine weather with the water they have absorbed during rain. Such a stone will probably, on microscopic examination, be found to contain minute fissures along which water will be absorbed to a considerable depth by capillary attraction. A wall built of such stone will be more permanently damp than one composed of stones of more open grain, which absorb even a larger proportionate weight of water; for water penetrates further and is retained longer in fine cavities than in larger ones.

Several means of PRESERVING the less durable stones have from time to time been suggested, painting either with lead paint or with oil being the most common, and requiring periodic renewal. Two liquid preparations of secret composition—Szerelmey's and the "Fluate" of the Bath Stone Firms—have also been much used for this purpose; but they are more valuable for rendering absorbent stones somewhat waterproof than for preserving them. It is better to use a durable stone in the first instance than to trust to these or any other preservative. They have, however, the advantage over other preparations of being colourless and not affecting the appearance of the stone to a material extent.

Of DESTRUCTIVE AGENCIES, water is the most to be feared, either from its proverbial "wearing" action, which is mechanical, and whose effect is seen in sea walls and on the "weather" side of buildings in exposed situations, or from its action as a solvent carrying destructive acids present in the air of large towns into the body of the stone, or from its expanding just previously to freezing after having been absorbed, and so splitting off small fragments of stone. Lichens, mosses, ferns, and creepers are also highly destructive, especially to limestones, both through the penetration of roots into the pores of the stone, and through the vegetation holding water like a sponge, and so giving time for any acid the water may contain to act. Water is thus again the actively destructive agent. Lodgment for it should never be provided, and such things as hollow mouldings, water-holding carving, and soffits unprotected by drips should be studiously avoided in external stonework.

NOTES FOR USERS.

Keep within the natural limits of size. You cannot obtain a stone 12 ins. thick from a quarry whose deepest bed is only 11 ins.

Stone is a weight-carrier, with little transverse and less

tensile strength. Use it, therefore, freely in compression, with caution as lintels, and never in tension.

Bring pressure upon it at right angles to its natural bed, or, in the case of slate, to its cleavage.

Arrange that each stone may be cut with as little waste as possible out of a roughly rectangular block, such as is obtained from the quarry.

Mouldings and carvings cannot be planted on. The effect must be obtained by sinking the hollows below the natural surface.

Avoid elaborate and undercut detail in the harder and in the laminated stones.

Avoid sharp arrises in the more friable stones, and where exposed to rubbing or weather.

Chapter V.

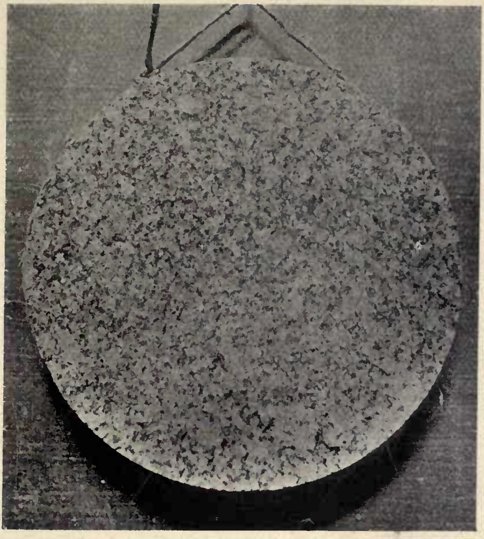
BASALT AND GRANITE.

BASALT, being hard and difficult to work, and mostly found in places from which transport is difficult, is little used structurally; and, as it has never been worth while to put down expensive plant, the method of quarrying is elementary. Owing to its columnar structure, it comes out of the quarry in long prisms. These, if placed on their sides and bedded in cement, make an excellent facing for sea-walls, where weight and indestructibility are primary considerations, and for this purpose they have been used in some parts of Ireland.

A decorative dark green Basalt is found near Exeter, however, which comes out in large beds, splits readily, and polishes well. Used structurally, it makes good hammer-dressed walling, especially for plinths and basements.

GRANITE, generally considered as igneous and intrusive, is, however, thought by many to be of sedimentary origin. It is a holo-crystalline aggregation of quartz, felspar and mica, its chemical composition varying with its mineral contents; and no less than 44 accessory minerals occur in it in varying proportions. Orthoclose, or potash felspar, is generally its principal constituent; its colour varies from white to flesh-red, and its grains are irregular and sharply defined.

It is usually thought to be a weather stone of undoubted quality; but this is not by any means always the case. Some granites are no better weather stones than the softer oölites, crumbling in the hand after a few years' exposure, and although most English and Scotch granites are reliable in this respect, the opinion of



ABERDEEN GRANITE.

DEVONSHIRE GRANITE (Blackenstone Quarry).

CORNISH GRANITE (De Lank Quarry).

[To face p. 40.

a mason accustomed to granite working should be sought where doubt exists. If exposed to fire it disintegrates badly.

GNEISS is a rock which has the same mineral constituents as granite, but is more or less stratified. It is very little used in building.

GRANITE is extensively worked, generally in large, open quarries. The beds as a rule are very thick; but still, horizontal beds do occur at intervals, and these often contain a very thin layer of sulphur. If, as sometimes happens, vertical joints of the same nature are found, the great natural blocks can be wedged apart. Otherwise, and more frequently, it is necessary to blast. Vertical holes are driven downwards (see Fig. 6), close against the new quarry-face which it is desired to expose, the quarry being worked in rough steps, as shown on sketch. These holes are made with a "jumper," which is a tool like a long bar of iron, weighted at about one-third of its length from the point with an attached ball of iron, and having a chisel edge. This the workman merely lifts, turns slightly, and drops, so that drilling a blasting hole is a slow process. After the circular hole has been made to the required depth, a notch is cut throughout its whole length in each direction in which it is desired for the rock to split. The number and position of these holes vary according to the block required, the charge, generally blast gunpowder, is proportioned so as to split the rock where required and lift it forward without unnecessarily breaking it up, and all the charges are exploded simultaneously.

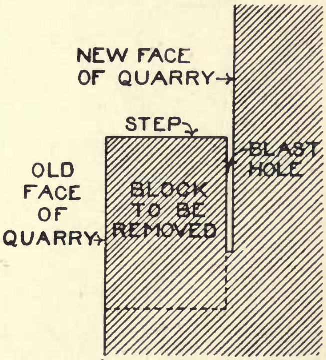


Fig. 6.

In many quarries, if the blocks have not been thrown over the old quarry-face by blasting, they are now levered to the edge till they fall over, and are removed from its foot by cranes and trucks, or by a more elementary system of wood rollers; while in other quarries it is necessary to use large cranes and lift the blocks to the top for transport. Rough irregularities are, however, always first knocked off with a heavy hammer, or the stone is split up into smaller blocks or slabs by making a series of holes, less in depth, larger in size, and closer together than the blast holes, and driving peculiar wedges into these. Two "feathers" are first inserted, these being of steel and resembling shoe-horns in shape, and then a steel "plug," in the shape of a truncated cone, is driven in between the feathers, as shown in sketch. The several plugs in a series have to be tapped in succession to ensure even driving and an uniform split.

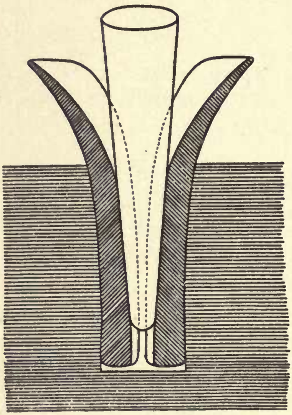


Fig. 7. Plug and Feathers.

Sawing, such as will be afterwards described when dealing with marble, is sometimes resorted to for producing slabs, but it is a tedious operation; and the same may be said of turning.

After splitting roughly to size with the plug and feathers (see Fig. 7), the next process is that of reducing surface irregularities with the *scabbling hammer* (see Fig. 8), which weighs about 22 lbs., and has a short handle. The flat, or "spalling," face is for knocking off irregular lumps and angles, or for roughly "hammer-dressing" the surface, while the pointed or "pick" face is applied vertically to the surface, being just lifted and allowed to drop of its own weight, this action being repeated rapidly by a skilled

workman and soon reducing a rough to a comparatively smooth surface, chips flying off in all directions. If the

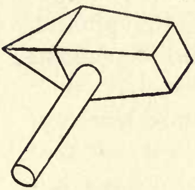


Fig. 8. Scabbling Hammer.

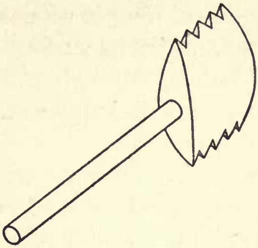


Fig. 9. Serrated Pick.

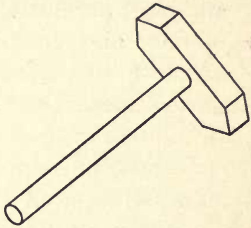


Fig. 10. Axe.

scabbler has two pick faces, and is known as a *scabbling pick*, it is somewhat lighter in weight, finer work being possible with it, while finer work still can be done with a pick having toothed edges, known as a *serrated pick* (see Fig. 9), or with an *axe*, such as is shown in Fig. 10, which only weighs about 9 lbs. It is this tool which is generally used to produce the so-called "draughted margins," with their parallel tool marks close together, though the same effect can be produced more tediously by means of a chisel (see Fig. 11).

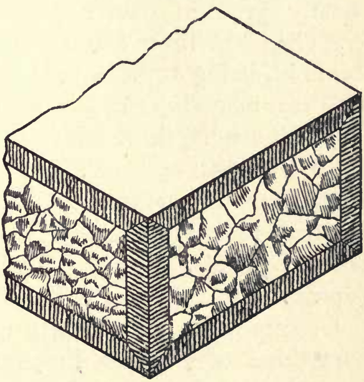


Fig. 11. Hammer Dressed with Draughted Margin.

The finest face, short of polishing, is obtained on Granite by the *patent axe*, which consists of a bundle of steel plates bound together, so that they can be taken apart and their edges sharpened when necessary.

Heavy machinery is necessary for polishing economically

on a large scale. The fine axed surface has to be ground down by rubbing on a revolving or travelling table in sand, the weight of the granite, which lies on the table, applying sufficient pressure. This rubbing is repeated, with material of finer and finer grain, until the surface becomes of that absolute smoothness known as high polish, the granite, during these later processes, being fixed, and movement being imparted to the rubbers.

Granite is used largely in building operations wherever stone is required to carry a heavy load or resist constant friction, as in plinths, columns, and pavings, while much is also employed for merely decorative effect. The waste blocks and chippings are commonly utilised also, the larger as road metal, and the smaller as the aggregate for concrete and artificial stone, so that the ultimate proportion of waste from a granite quarry is small.

DEVONSHIRE AND CORNISH GRANITES (see Pl. I.) are mostly grey in colour, with distinct black and white crystals, that from the De Lank quarry, six miles from Bodmin, being typical, very hard and durable, and with a well compacted grain, in which hornblende abounds.

Farther west, however, near PENZANCE and the LAND'S END, the granite is of a more yellow colour, and contains large felspathic crystals known as "horses' teeth." This is known as PORPHYRITIC GRANITE, and is highly decorative when polished. That from the Blackenstone quarry is typical.

Granite from the CHANNEL ISLANDS is close in grain, sometimes of a bluish tinge (though several colours are found), and generally very hard.

LEICESTERSHIRE GRANITE is a true syenite. It makes excellent road metal, but except locally is not much used for building, being tough and compact, except as the aggregate for artificial stones and concrete. It is often green in colour.

The SHAP GRANITE of Westmorland is one of the most beautiful found in England, containing large red felspar crystals, and taking a high polish.

Most of the SCOTCH GRANITE is blue-grey, and it is generally admirable for all purposes for which granite is used. There are extensive quarries in Argyleshire, Kirkcudbrightshire and Kincardineshire, but the principal ones are in Aberdeenshire, in which county are also found the beautiful red Peterhead and Cruden granites. The Peterhead is particularly well known, both the colour and polish being admirable. The grey granite fades more or less after continued exposure. It is composed of small grains.

IRISH GRANITE is not much used except locally, though a great deal exists in the counties of Dublin, Donegal, Louth, Galway and Mayo, most of it being grey, though some of a red colour is found in Galway and Donegal.

A large amount of excellent granite, grey, blue and red, is now imported from NORWAY and RUSSIA, as, owing to the low rate of wages obtaining in those countries, it can be put upon the London market at a low price. Amongst this is a granite, nearly black in colour, containing large crystals, which have a peculiar "flash" when polished, which, if introduced sparingly, may be used amongst other stones with good effect. There is doubt, however, whether these foreign granites will retain their polish and colour well externally.

ENGLISH GRANITES.

Quarry.	Size of Blocks.	Port.	Station.	County.	Weight per cubic ft. in lbs.	Crushing Resistance per super ft. in tons.	Colour.	Remarks.
Bardon Hill	...	...	Bardon Hill, Midland Rly.	Leicestershire	...	2,802	Blue.	Used mainly for macadam road metal; much used in Midlands.
Blackenstone	Up to 12 ft. by 5 ft. by 4 ft.	...	Moreton-Hampstead, G. W. Rly.	Devonshire	168	...	Dark grey	Used for paving in Exeter and buildings; a porphyritic granite with large brown crystals.
Charnwood	...	...	Shepshed, L. N. W. Rly.	Leicestershire	...	3,452	Blue	Used for setts, curbs, etc.; syenite.
Cliff Hill	...	...	Bardon Hill, Midland Rly.	Leicestershire	176	2,133	Grey	A syenite; chiefly used for paving.
De Lank	Any size	Wadebridge, Padstow, Fowey.	Wenford siding, L. & S. W. Rly.	Cornwall	180	1,171½	...	Very hard, good granite; very large stones, fine and close grained. Used in works at Milford, Portland, Devonport; Beachy Head Light-house; Blackfriars Bridge; Wax Chandlers' Hall, City.
Lamorna	...	...	Penzance, G. W. Rly.	Cornwall	...	...	Grey	Used at Devonport Dockyards.
La Moye	Up to 70 cubic ft.	St. Heliers	St. Heliers	Jersey	165	...	Grey	Good building stone; syenite; used chiefly for paving setts and road metal.
Markfield	...	...	Bardon Hill, Mid. Rly.	Leicestershire	...	1,656	Greenish grey	A syenite; used for paving and road metal.
Mountsorrel	...	Wharf on Leicester Canal	Mountsorrel, Mid. Rly., Swithland siding, G. C. Rly.	Leicestershire	166	...	Pink and grey	Syenite; used chiefly for paving and road metal.
Rowley Regis	...	...	Rowley Regis, G. W. Rly.	Staffordshire	...	...	...	
Royal Oak	...	Plymouth	Tavistock, G. W. Rly.	...	170	...	Grey	
Shap Fell	Up to 300 cubic ft.	...	Shap, L. N. W. Rly.	Westmorland	160	1,200	Greyish pink	Used for dock and bridge work. A porphyritic granite, containing large flesh-coloured crystals of felspar (orthoclase); takes a fine polish; converted by machinery. Mausoleum, Lowther Castle; columns in Hull Museum; columns, St. Pancras Station; posts, Western area, St. Paul's.

Shepton Mallet (*Basalt*)	...	...	Shepton Mallet and Cranmore, Mid. & L. & S. W. Rlys.	Somerset-shire	...	2,592	Dark blue	Extremely hard; used for road-making purposes.
Stoney Stanton	...	...	Stoney Stanton, L. N. W. Rly.	Leicester-shire	170·5	...	Dark grey	A syenite; used for paving setts, curbs, etc.

SCOTCH GRANITES.

Avochie	24 cubic ft.	...	Rothiemay, G. N. of Scotland	Aberdeen-shire	180	...	Grey	
Blackhill	Up to 80 cubic ft.	Cruden	Longhaven, G. N. of Scotland	Aberdeen-shire	170	...	Dark red	Suitable for polished and axed work; takes a beautiful polish; turned by machinery into columns, etc.
Craignair Dalbeattie	...	...	Dalbeattie, G. & S. W. Ry.	Kirkcud-brightshire	213	...	Grey	Used for Swansea docks.
Creetown	Up to 120 cubic ft.	Creetown	Creetown	Kirkcud-brightshire	186	...	Light grey	Used for monumental and building purposes; several quarries; known as "silver grey," and is the lightest in colour of any Scotch granite.
Hill O'Fare	Up to 100 cubic t.	Aberdeen	Banchory, G. N. of Scotland	Kincar-dineshire	224	...	Rich dark red	Fine grain; used chiefly for monumental work.
Peter-head	Any size	Peterhead	Peterhead, G. N. of Scotland	Aberdeen-shire	165·9	...	Grey	Pillars, Carlton Club. Good colour; coarse grained; composed of red orthoclase, albite, black mica, quartz. Good to polish; used for pedestal of Peel's statue, Cheapside, London.
Rubislaw	Any size	Aberdeen	Aberdeen, G. N. of Scotland	Aberdeen-shire	163·7	1,289·7	Blue-grey	Chiefly used for polished monumental and architectural work; buildings in Aberdeen; used in London for curbs, paving, monumental work, etc.: Bell Rock Lighthouse.
Torris Forest	...	Aberdeen	Kintore, G. N. of Scotland	Aberdeen-shire	160	...	Grey	Used for monumental work, docks, and paving setts. Very like the granite from Kemnay.

WELSH GRANITES.

Quarry.	Size of Blocks.	Port.	Station.	County.	Weight per cubic ft. in lbs.	Crushing Resistance per super ft. in tons.	Colour.	Remarks.
Anglesea	...	...	Holyhead, L. & N. W., G. W., Mid. Rlys.	Anglesea	...	...	White	Used for Holyhead Breakwater.
Darbishire's	Various	Conway	Penmaenmawr	Carnarvonshire	166	3,646	Grey	Diorite road metals, setts, etc.
Penmaenmawr	...	Conway	Penmaenmawr	Carnarvonshire	...	...	Grey	Diorite ; road metals, setts, etc.

IRISH GRANITES.

Dalkey	Up to 520 cubic ft.	Arklow	Aughrim, Dublin, Wicklow & Wexford Rly.	Wicklow	169·6	...	Bluish grey	Hard, fine grained stone, with little or no mica. A good stone for building, road metal and pavings, etc. ; hard to work ; St. Uerburgh's and St. Paul's Churches.
Kingstown	...	Bulloch	Dublin, Dublin, Wicklow & Wexford Rly.	Dublin	171	...	Bluish grey	Hard and durable ; hard stone to work ; Kingstown railway station.
Castlewellan	Up to 660 cubic ft.	Newcastle	Newcastle Belfast and co. Down	Down	172·3	...	Mottled grey	Used for monumental work, landings, etc. ; used for base and pedestal of Albert Memorial, and Eddystone and Blackbeat Lighthouses.

Chapter VI.

SLATE.

THERE are two methods of obtaining slate—by open quarrying and by mining. Of these, the open quarry is the more usual except in and around Festiniog, the open quarries at Bethesda and Llanberis being well known as some of the largest of any sort in the world.

Whichever system is employed for reaching the slate, however, the process of dislodging it is that of blasting. When a quarry face has been exposed, a vertical channel about 3 ft. square has to be chipped out throughout its height. A horizontal hole has now to be made at a convenient depth, known as a "*split hole*," along the cleavage and preferably in a natural joint, and a carefully proportioned blast exploded in this just to lift the rock. Then another hole, known as a "*pillar hole*," is driven in at right angles to the cleavage and down to the "split" caused by the previous charge, thus bursting the stone out at the split and towards the already exposed channel along an imperfect cleavage, perfect enough for this purpose, called the "*pillaring line*," which always runs north and south. The blast holes are made with the jumper when vertical, and when horizontal or nearly so with a long chisel (with shield) and a hammer, the men having often to let themselves down by ropes to their work. At the Bettws-y-Coed slate quarry, the one which was inspected for the purpose of writing this description, natural joints occur in an erratic fashion, crossing one another so sharply as to produce razor-like edges, and yet each continuing, beyond the crossing, in its own plane.

Around Festiniog the slate generally underlies granite,

and has to be mined. Almost invariably a tunnel is driven in from the outcrop under the granite roof, with branches at convenient depths, from which chambers are worked under one another, the chambers being 30 ft. wide with 30 ft. pillars of solid rock left between. Thus only half the rock contained in a slate mountain is ever removed, owing to the necessity of leaving these pillars to support the roof above. This is known as the descending system (see Fig. 12).

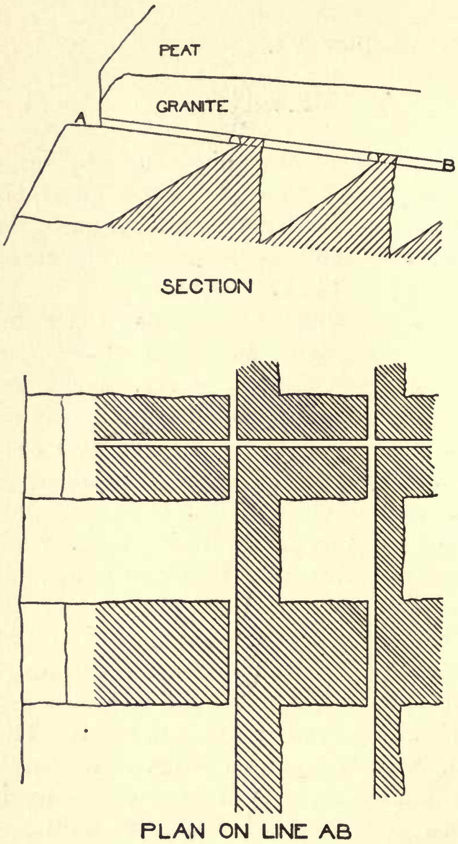


Fig. 12. Slate Mine.

At the Rhiwbach quarry, near Blaenau-Festiniog, which produces roofing slate only, an attempt is being made to reduce the enormous waste—often 14 tons of rock having to be removed to produce one ton of finished slates—by working on an ascending system and using a machine wire saw instead of blasting. A steel wire rope, $\frac{1}{4}$ in. in diameter, running in granulated slate and worked by compressed air, is made to take off a clean slice of rock

face no less than 150 ft. in length, and this, once cut, may be split up into convenient sections along the cleavage and the pillar line with heavy broad-edged wedges.

The blocks thus dislodged are split along the cleavage, by wedges or plug and feathers, into slabs of not more than 13 ins. thick and then taken to the workshops or "mill." There the slabs are first sawn into lengths, according to the purpose for which they are required. Circular machine saws are used, the stone being brought to them on travelling tables. Thin slabs can be cut by toothed saws running in water, but the thicker slabs are cut by a saw having steel

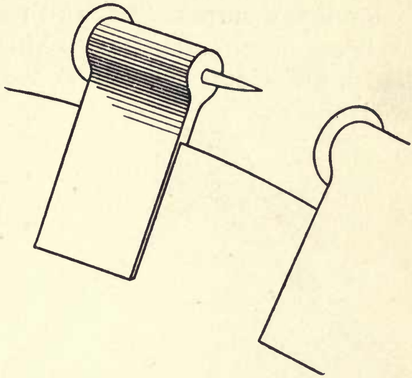


Fig. 13. Tooth of Circular Saw.

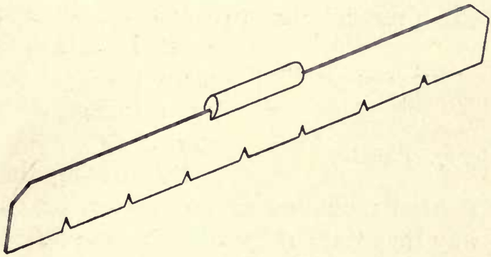


Fig. 14. Hand Saw.

scupper nails set into the blade to serve as teeth, the rotation being so arranged that the head of the nail first meets the slate and acts as a cutting edge, forming a broad groove (see Fig. 13). Whichever form of blade is used, there are two blades on each spindle acting simultaneously

against the same slab, and so cutting exact lengths, which are adjustable. A hand saw, having a few **V**-shaped notches in place of teeth, and working in water, can also be used, but its employment is more tedious (see Fig. 14).

For many purposes for which slate is used, such as for shelving, cisterns, hearths, paving and urinal sides and backs, the widths as well as the lengths are sawn, and

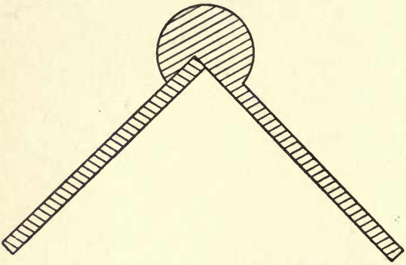


Fig. 15. Slate Ridge in Two Pieces.

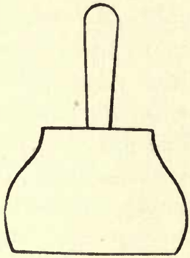


Fig. 16. Mallet.

one or both faces are planed. This is done by passing the slabs, resting again on a travelling table, under a broad plane iron, 8 ins. or more wide, set in a frame so as to take off any desired thickness of shaving, and the surface thus produced can if required be further smoothed, or "polished" as it is called, though no really polished face results, by rubbing with pumice stone.

Fig. 17. Chisel.

By altering the planing iron any desired moulding or groove can be cut; and it is in this way that slate ridge rolls are made (see Fig. 15).

Chamfers, and mouldings also, can likewise be cut by hand with a large-headed wooden mallet (Fig. 16) and steel chisel (see Fig. 17), such as is used by masons for softer stones, and finished with a file and emery paper—or rounded nosings are even filed only, without previous chiselling.

When required for roofing, the slate slabs sawn to length

are split along the cleavage to not more than 3 ins. thick, and then "pillared," or split across the cleavage with a *pillaring chisel*, having an edge about an inch wide, driven with a heavy iron hammer. The slabs thus roughly reduced to size are now taken between the knees of the splitter. He gauges the thickness of a slate by eye, varying it according to the class of rock he is dealing with, and drives in a *splitting chisel* (see Fig. 18), having a thin, wide blade, along the edge with a light iron-bound wooden mallet (see Fig. 19). Very thin slabs of the higher quality slates are obtainable, and the splitting is, as a rule, readily done by a trained man.

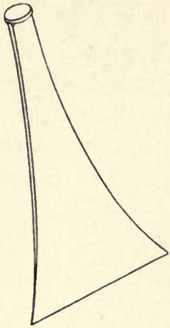


Fig. 18. Splitting Chisel.

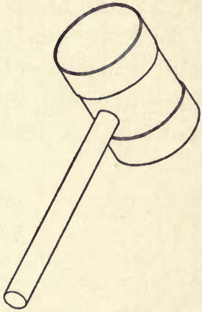


Fig. 19. Light Iron-bound Wooden Mallet.

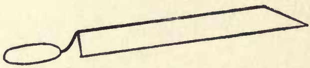


Fig. 20. Dressing Knife.

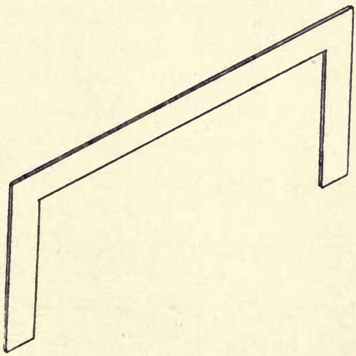


Fig. 21. Travel.

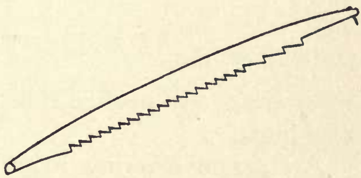


Fig. 22. Measuring Stick.

The slates thus obtained are trimmed to market sizes with a *dressing knife* (Fig. 20) acting against a *travel*

(Fig. 21), this last being a tool resembling a door scraper with a knife edge—the sizes being first marked on the slate by a nail in a notched *measuring stick* (Fig. 22), the notches being graduated to give every inch from 6 to 18, and then 20, 22 and 24 ins.

In many quarries trimming is now done by machinery, with what look like gigantic scissors whose lower blade is fixed horizontally while the upper blade is made to rise and fall. A fixed plate against the side determines the

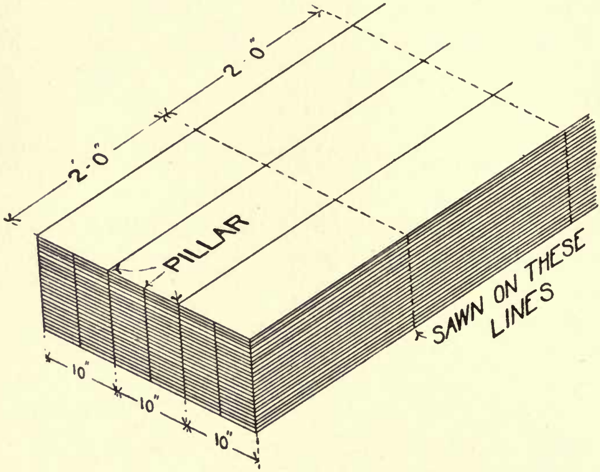


Fig. 23. Diagram of Slate Cleavage.

right-angle, and against this the notched measuring stick is also fixed.

A diagram showing roughly how a block may be split along cleavage and pillar is given in Fig. 23.

Roofing slates are sorted at quarry according to size and weight, and not according to the trade names by which certain sizes have become known ; and the sizes obtainable are much more varied than is generally supposed, as the following list will show. While the larger sizes only are used in London to any extent, they are scarcely known in

the North of England and Scotland, where small sizes are much preferred :—

TABLE OF ROOFING SLATES FROM THE BETTWS-Y-COED QUARRIES.

Size in inches.	Weight per 100 in cwts.	Trade Name.	Size in inches.	Weight per 100 in cwts.	Trade Name.
24 × 14	8	Princess.	16 × 9	$3\frac{1}{4}$	...
24 × 12	7	Duchess.	16 × 8	3	Ladies.
22 × 12	$6\frac{1}{2}$	Small Duchess.	14 × 12	$3\frac{3}{4}$	...
22 × 11	6	...	14 × 10	$3\frac{1}{2}$	...
20 × 12	6	...	14 × 9	$2\frac{3}{4}$	...
20 × 10	$4\frac{3}{4}$	Countess.	14 × 8	$2\frac{1}{2}$	...
20 × 9	$4\frac{1}{4}$	...	14 × 7	$2\frac{1}{4}$	...
18 × 12	5	...			
18 × 10	$4\frac{1}{4}$	...	Also 13 × 10, 13 × 7, 12 × 10, 12 × 9, 12 × 8, 12 × 7, 12 × 6, 12 × 5, 10 × 8, 10 × 6, 9 × 8, and 9 × 6.		
18 × 9	$3\frac{3}{4}$	Small Countess.			
16 × 12	$4\frac{1}{4}$	...			
16 × 10	$3\frac{3}{4}$	...			

Roofing slates are known as "Firsts," "Seconds" and "Thirds," the quality depending on freedom from flaws as well as upon evenness of colour and thickness, it not being always the thinnest slate which is the best.

If good slate be stood in water, the damp should not rise at all perceptibly up its edge above the water line, even in 24 hours; while in a bad slate it will rise as much as 2 ins. in ten minutes. A bad slate, also, will give off an earthy odour when wetted, and when struck will sound dull, while a good slate gives off a sharp metallic ring.

Slates are sold from the quarry by "long tally"—that is, per thousand of 1,200, with 60 extra to allow for breakage, making a total of 1,260 to the thousand. By the time they reach the builder, a thousand usually consists of 1,200 only.

The following analyses of Bettws-y-Coed and Portmadoc slates are from Davis's "Chemical Engineering," and show both to be good, the former, as containing less oxide of

iron and lime, being the better able to withstand the action of acids in chemical works :—

—	Bettws-y-Coed Slates and Slabs.	Portmadoc Slate.
Silica	61·26	58·91
Alumina	20·49	23·08
Oxide of iron	7·23	9·02
Lime...	1·08	2·06
Magnesia	1·96	1·14
Potash	2·18	1·92
Soda	2·38	1·02
Water	3·44	2·85

The specific gravity of slate, like that of all other compound minerals, varies slightly, but is about 2·85, and its weight is about 178 lbs. per cubic foot. The tensile strength, rarely called into play in practice, is about 630 tons per square foot, and its crushing strength varies from 720 to 1,205 tons per square foot. As to its transverse strength, this is difficult to express, and it can only be said that it is such as to render it the best of all stones for use in weight-carrying lintels.

Easily split, planed and sawn, it is yet extremely tough and wear-resisting.

There is a great amount of wastage both in quarrying and working, no use for the detritus having yet been found, save that the larger blocks of rock which, containing hard veins or otherwise, are useless for conversion, are employed for walling in the locality of the quarries.

In some districts, iron pyrites are found in the slate beds, and cause a great deal of trouble to the quarry owners; but roofing slates and slabs containing them are rarely put upon the market.

"Best" or "First" slates, according to the general acceptance of the term, must be thin, of straight cleavage and good colour, and free from spots; but above all they must be thin. In this respect the classification is

unfortunate, for while thin slates make very light roofs, they are liable to breakage, and the monotonous smoothness is hardly so pleasing, to many architects, as the comparative roughness of a thicker slate.

Thin blue slates are principally shipped from Bangor, and are known as "Bangor slates," though obtained from the great quarries at Bethesda and Llanberis, and from smaller quarries in the same district. "Best Bangor" are perhaps the finest slates procurable for perfect uniformity of colour, smooth texture, and extreme thinness.

"Portmadoc slates" are also named from the port of shipment, as they are not quarried at Portmadoc, but in the neighbourhood of Festiniog. They are slightly thicker and coarser in grain than "Bangor slates" and of a more purple colour.

Bettws-y-Coed slates are shipped from Deganwy. Though free from blemishes they are classed as "Seconds" and "Thirds" only, as they are not thin splitting. Where a little additional weight is not objected to they make admirable roofing slates. The colour is a pleasant dark blue. Very large slabs are obtainable. Blocks can be sawn up to 14 ft. square and planed up to 12 ft. by 6 ft.

A green slate with a peculiar permanent red flash upon the surface is quarried at Precelly, in South Wales.

Westmorland slates, especially those from the Elterwater and Tilberthwaite quarries, are of a beautiful green colour, thick and rough. They are not arranged in sizes before being sent from the quarry, and so have to be purchased "mixed." Usually the longer slates are laid near the eaves of a roof and the smaller ones near the ridge; and as the widths as well as the lengths vary, broken jointing results. Laid by skilled hands this can be made to look very well. These Westmorland green slates, it may be mentioned, are not clay formed, but are composed of volcanic ash which has been altered by metamorphism.

Though good slates are obtainable from Cornwall, Scotland and Ireland, they are not much used except locally.

Soft, earthy slates are also quarried in Somersetshire, but they are not of great value for roofing purposes. The Irish slates from Valencia and Killaloe are particularly good, and occur in large quantities, but the difficulties of transport are great, and seem to prohibit their use to any great extent. They are all purple in colour. The Cornish slates are mostly used for slabs.

American slates have been imported and largely used in cheap work of late years. They are mostly blotchy, and of unpleasant purple, green, or red colour.

Portuguese slate is imported, mostly for enamelling—for it lacks some of the qualities necessary for a good roofing slate. It is somewhat earthy, but is soft to work, is easily brought to a smooth surface, and stands well the temperature of the ovens.

Enamelled slate is used principally for chimney pieces. At Messrs. Lee & Brothers' Works at Hayes, the slate, after being planed, is placed on a rubbing bed before the colour is applied. The colour first used is black, and with this the whole surface to be enamelled is covered. As this is done, the slabs are arranged in iron racks so that the air can get all round them, and the racks, running on tram lines, are wheeled into large ovens and subjected to a dry temperature of about 300 degrees F. On removal, any desired colours are applied by skilled enamellers, either to imitate marble veinings, or to produce patterns or even landscapes, the "brushes" used including coarse sponges and feathers. Stoving is repeated, sometimes only once, but usually more often, lower temperatures being used for the colours than for the black groundwork; and the work is finished by varnishing and polishing with rotten-stone.

The various slabs which compose fire-place jambs are fixed together before they leave the works, hook-shaped iron cramps being screwed and leaded into the back of the slabs and these held together with a plentiful supply of plaster of Paris, in which lumps of broken marble are embedded.

ENGLISH SLATES.

Quarry.	Nearest Station.	Nearest Port.	Colour.	Remarks.
Delabole, Old	Delabole, L. & S. W. Rly. N. Cornwall	Wadebridge	Blue-grey	The slate is noted for its lightness, durability, and strength.
East Cornwall	Doublebois, G. W. Rly. Cornwall	Par	Blue	Slate very durable.
Elterwater	Coniston, or Windermere, L. N. W. Rly. Lancashire.	Barrow-in-Furness	Finest light green	Rough in texture, but of a durable character.
Honister	Keswick, Cumberland.	Maryport or Workington	Light sea green, Deep olive green, dark sea green	
Kirkstone	Windermere, L. & N. W. Rly. Westmorland	Barrow	Green	Very strong and durable.
Launceston	South Petherwin, Cornwall.	...	Blue	
Okehampton	Wiveliscombe, G. W. Rly. Somersetshire	Watchet	Blue and variegated	Slate slabs; damp courses, etc.
Parrock End	Coniston, F. Rly. Lancashire	Barrow-in-Furness	Light sea green, deep olive green, dark sea green	Slate of rich tint.
Tilberthwaite	Tilberthwaite, Lancashire	...	Green	
Torver	Torver, F. Rly. Lancashire	Barrow-in-Furness	Blue	
Tracebridge	Burlescombe, G. W. Rly., 3½ miles Wellington, G. W. Rly., 6 miles Wiveliscombe, G. W. Rly., 6 miles Milverton, 7 miles Somersetshire	...	Dark blue	Mostly used for slabs, pump troughs, cisterns, hearths, flooring, chimney tops, garden edging, etc.
Treborough	Washford, G. W. Rly. Somersetshire	Watchet	Blue	Roofing slates, and slate slabs for all purposes.
Yeolmbridge	Launceston, L. & S. W. Rly. & G. W. Rly. Devonshire	Plymouth	Blue veined, grey hard	Chimney pieces, water tanks, sills, steps, paving, etc.

SCOTCH SLATES.

Aberfoyle	Aberfoyle, 2½ miles, N. B. Rly. Perthshire	Bowling	Blue and green	Only roofing slates manufactured.
Balvicar	Oban, N. B. & C. Rlys. Argyleshire	Glasgow	Blue	This slate is blue in colour, with small iron pyrites.
Belnahua	Oban, N. B. & C. Rlys. Argyleshire	Belnahua	Blue	

SCOTCH SLATES—*continued.*

Quarry.	Nearest Station.	Nearest Port.	Colour.	Remarks.
Breadalbane	Oban, N. B. & C. Rlys. Argyleshire	Luing and Talevonochy	Blue	
Craiglea	Methven, C. Rly. Perthshire	Perth and Dundee	Blue, green and grey	Made in all the different sizes.
Cullipool	Oban, N. B. & C. Rlys. Argyleshire	Cullipool	Blue	

WELSH SLATES.

Aberllefenny	Aberllefenny, transhipped at Machyulleth, Cambrian Railway Merionethshire	Aberdovey	Dark blue	
Alexandra	Dinas Junction, L. & N. W. Rly. Carnarvonshire	Carnarvon	Purple	
Bettws-y-Coed	Bettws-y-Coed, L. & N. W. Rly. Merionethshire	Deganwy	Dark blue	Carnarvon vein; durable hard slate; large vein producing largest size slabs and slates; large quantities of slabs for mantel-pieces and slates of all sizes; strong and durable.
Cefn	Kilgerran, G. W. Rly. Pembrokeshire	Cardigan	Blue	
Cilgwin	Nantlle, L. & N. W. Rly. Carnarvonshire	Carnarvon	Blue, purple	
Dinorwic	Port Dinorwic, L. & N. W. Rly. Carnarvonshire	Port Dinorwic	Grey, blue, red and green	The slate is hard and very durable.
Diphwys Casson	Blaenau-Festiniog, L. & N. W. Rly. Merionethshire	Portmadoc	Blue	
Dorothea	Nantlle, L. & N. W. Rly. Carnarvonshire	Carnarvon	Blue and purple	
Glynrhonwy	Llanberis, Snowdon Mountain Line Carnarvonshire	Carnarvon	Blue and purple	Strong, hard slate.
Llechwedd	Blaenau-Festiniog, L. & N. W. Rly., G. W. Rly., Festiniog & Portmadoc Rly. Merionethshire	Portmadoc	Dark blue	
Moelferna	Glyndyfrdwy, G. W. Rly. Merionethshire	Saltney	Blue black, blue	Roofing slates; slate slabs for brewery tanks.
Oakeley	Blaenau-Festiniog, L. & N. W. Rly. Merionethshire	Portmadoc, N. Wales	Blue	The slate is known to the trade as "Oakeleys."

WELSH SLATES—*continued.*

Quarry.	Nearest Station.	Nearest Port.	Colour.	Remarks.
Penrhyn	Bethesda, L. & N. W. Rly. Carnarvonshire	...	Purple	
Rhiwbach	Blaenau-Festiniog, L. & N. W. Rly. Merionethshire	Portmadoc and Deganwy	Blue	One of the oldest quarries producing Portmadoc slate; worked from 1812.
Votty and Bowydd	Blaenau-Festiniog, G. W. and L. & N. W. Rlys. Merionethshire	Portmadoc	Blue	Genuine Portmadoc or Festiniog slates.
Wrysgan	Tan-y-Grisiau, Festiniog Rly. Merionethshire	Portmadoc	Blue	

IRISH SLATES.

Fourcoil	Skibbereen and Clonakilty, 10 miles each, Co. B. & S. C. Rly. Cork	Leaf Quay, Glurdere Harbour	Dark blue	
Garrybeg	Nenagh and Killaloe, G. S. & W. Rly. Tipperary	Limerick	Grey	
Madrana	Skibbereen, 9 miles, Cork, Bandon and S. C. Rly., Cork	Leap, 2½ miles	Very dark grey	
Ormonde Slate	Carrick-on-Suir, 5½ miles, G. S. & W. Rly. Kilkerry	Carrick-on-Suir, 6 miles	Blue	
Valencia	...	Valencia Island, Kerry	...	Billiard table beds.

Chapter VII.

MARBLE.

MARBLE is in some cases easily quarried, as it occurs naturally in blocks of convenient size, needing only to be levered out; but more frequently blasting or wedging have to be resorted to. In the ancient workings of the quarries near Larissa, from which the Verde Antico was obtained, it has been found that columns were cut with infinite labour out of the solid rock, the stone around them being chipped away so as to leave the rough columns standing, these being finally severed at their bases.

Foreign marble generally reaches England in roughly-squared blocks, but the more valuable statuary marble of Italy is sent over just as it is obtained from the quarry, and is invoiced neither by weight nor cubic content, but simply as "One block of Marble," the price being stated in an equally simple manner, as £100, £150, or £200, as the case may be.

Marble masonry is a thing to itself, requiring heavy machinery and infinite patience. At Messrs. Lee & Brothers' large works at Hayes, the blocks are lifted from barges by a crane running on a gantry, and are deposited under cover in a large shed, the power employed for this and all the other machinery being electricity generated by a dynamo driven by a gas engine, the gas for which is made on the premises.

When it is required to cut a block into slabs it is put upon a table at ground level and a series of steel blades are suspended horizontally over it in a rocking frame, at such distances apart as correspond with the thickness of the slabs required. As these blades, or saws, swing

DEVONSHIRE MARBLE
(Characteristic of all true Marbles).

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horizontally, they are supplied with fine sand from a hopper in which rollers revolve to crush any coarse particles, the sand passing from the rollers to a fine rocking sieve, through which it is washed with a plentiful supply of water. In this way as many as twenty, or even more, blades can be worked simultaneously upon the same block of marble, but even so the process of sawing is extremely slow.

In order to cut the slabs thus produced to their required sizes, several are piled on one another till a depth of about 12 ins. is reached, and placed on a slow travelling table in front of a circular saw. This has a steel blade with diamonds set in sockets on its edge, and does its work with comparative rapidity, the rate of "feed" being adjusted according to the total thickness to be cut through. Water only is supplied to this saw.

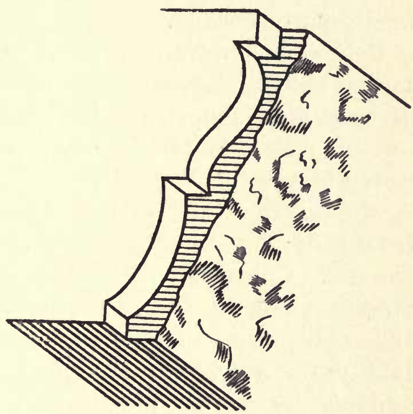


Fig. 24. Marble Hord (Starting of Machine-cut Mouldings).

The edges are next ground on a revolving iron table in sand and water, and the square slabs are then bedded in plaster of Paris on a wooden frame, to a perfectly true surface, on a setting of brickwork. Over this frame is a revolving arm to which can be attached revolving rubbers of various kinds. The first of these to be used has iron pads, which work in sand to grind down minor surface irregularities and remove any rust stains left by the saws. This acts for eight hours, moving rapidly over the face of the marble and attacking all parts equally, and then is replaced by a rubber having rope pads working in emery for another eight hours, the

final polish being applied by a rubber with felt pads working in putty-powder (oxide of tin) for a similar period of time.

Straight mouldings, if started by hand as shown in Fig. 24, can be cut by machine on a travelling table under narrow plane irons, but on curves they have to be worked laboriously by chisel and mallet, as must all carving and sculpture. All the various grinding and polishing processes on such work is also done by hand—and exceedingly tedious it is—sand being first used to remove the tool marks, then pumice-stone, then snake-stone, and finally putty-powder.

Columns, however, even up to 16 ft. in length, can be turned and polished by machinery, even the entasis being given in a way which needs little after working to correct; but breakage sometimes occurs in the machine, entailing heavy loss.

Most of the white marble now used for statuary comes from Italy, the Pentellic marble of Greece being no longer worked. Carrara marble is best known, with its sugar-like structure, but the Serverezza marble, which is glassy rather than saccharine in fracture, is almost to be preferred. Of late years a white marble, slightly veined and so not suitable for statuary, has been imported from Norway for use in thin slabs as wall linings and counter tops.

Most of the veined marble in common use at present comes from the Pyrenees, whence many colours and most beautiful markings are obtainable, impossible to classify, and only to be selected from samples.

The best known coloured Italian marbles are yellow, that from Verona light and pure in tone, and that from Sienna of deeper tint with purple markings.

Greece produces a very fine green marble, known as Cippolino, which, however, requires expert cutting if the marking is to be displayed to advantage.

The most beautiful marble known, probably, is also green, with crystals of white set in it as if it were a natural mosaic. This is the Verde Antico, which supplied the

monolithic columns of Sta. Sophia at Constantinople, as well as most of the decorative marble work of Italy for many centuries. The quarries, which for a long period of time were lost, have recently been discovered near Larissa, in Turkey, and are now being worked by an English company. This marble is often referred to as "porphyry." It is easily distinguished as being a "breccia" of angular fragments of light and dark greens, with pure statuary white, the whole being cemented together with a brighter green, while the snow-white patches usually have their edges tinted off with a delicate fibrous green radiating to the centre of the white. The cementing material is also of the same fibrous structure.

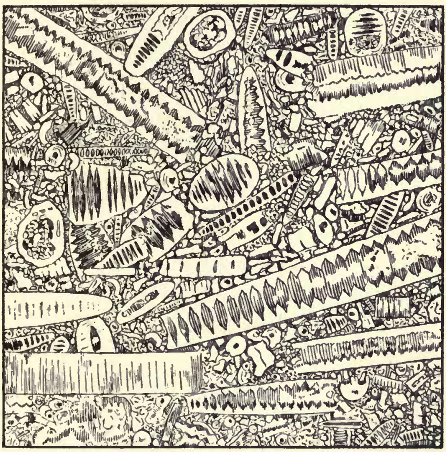


Fig. 25. Appearance of a Polished Specimen of Barton Limestone.

Another beautiful green marble is the Connemara, from Ireland, but it is not obtainable in very large blocks; and other true Irish marbles are the rich Cork red, the Kilkenny black and white, and the Galway black.

Devonshire marble (see Pl. II.) lies in a narrow belt which passes from Torquay through Totnes and Ashburton to near Plymouth, avoiding the Moors. Many different colours are obtainable, the tints being as a rule delicate rather than striking, making it suitable for internal wall-linings, chancel floors and steps, and other decorative uses.

Purbeck "marble" is really a hard, South of England limestone, capable of receiving a good polish, which, however,

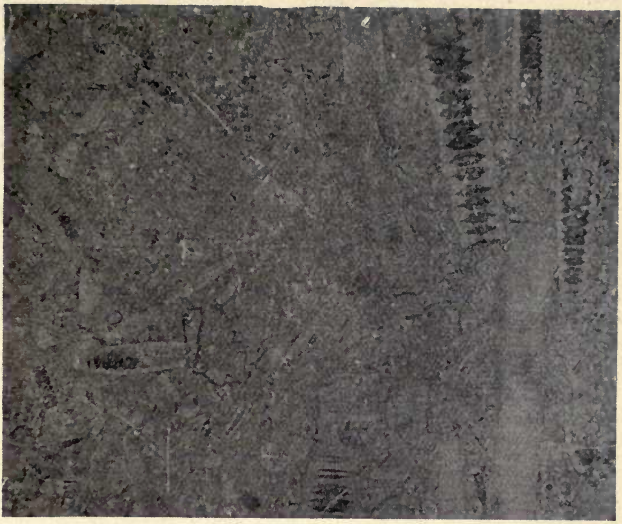
it does not retain very well. It is of a deep blue colour, with fossil shells well displayed, and, though little used now, it was employed largely in the thirteenth and fourteenth centuries for small detached shafts, bases and string mouldings.

Somewhat similar stones, though lighter, and sometimes yellowish in colour, are found in Derbyshire, in larger slabs than the Purbeck, rendering them useful for steps, floors and wall linings. Such is the fine-grained Hopton-Wood stone, which comes out in large blocks and weathers well; and also the beautiful fossiliferous Barton Limestone (see Fig. 25 and Pl. III.).

The following chemical analysis of the Hopton-Wood limestone was made by Mr. E. W. T. Jones, F.C.S. :—

Moisture...	0·10	per cent.
*Lime	55·30	„
Magnesia	0·45	„
*Carbonic Acid Gas	43·60	„
Oxide of Iron and Alumina ...	0·25	„
Phosphorus	traces only.	
Sulphur	—	
Siliceous matter	0·75	per cent.
	100·45	

*Equal to Carbonate of Lime ... 98·90



Barton Limestone.

Hopton-Wood Stone.

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ENGLISH MARBLES.

Quarry.	Nearest Station.	Nearest Port.	Colour.	Remarks.
Anglesea	Isle of Man	...	Black	
hudleigh	Chudleigh, G.W. Rly. Devonshire.	Teignmouth	Dark blue-grey with white marking	Used for chimney pieces.
Drews-leighton	Yeoford, L.S.W. Rly., 7 miles; Moreton, G. W. Rly., 7 miles. Devonshire.	Exeter, Fremington, and Teignmouth	Blue	The marble is burnt for lime, and is excellent for building purposes and road metal. It looks well when used with granite.
Ipplepen	Stoneycombe siding. Devonshire.	Teignmouth, 8 miles	Pink	Blocks 18 ft. square sent to London. Used for shafts of columns, National Provincial Bank, Bishopsgate Street.
Petit Tor	Torre, G. W. Rly. Devonshire.	Torquay	Pink, yellow, dove, light and dark grey	Known as Babbicombe marble. Some blocks consist entirely of fossil corals, and are known as Madrepore marble.
Purbeck	Swanage, L. & S. W. Rly. Dorsetshire.	Swanage	Dark blue or grey	It is composed entirely of fossilized shell-fish about the size of a pea. It has been largely used in nearly every cathedral in England for columns, and is to be found in many ancient churches for fonts, etc. It occurs in beds from 6 to 9 inches thick.
Ramsley	Newton Abbot, G. W. Rly. Devonshire.	Torquay	Red, grey	
Scarlett	Castletown, Manx Northern Rly. Isle of Man.	Castletown	Grey	Hard and durable. The stone lies in perfect layers from 2 in. to 3 ft. in thickness. The famous Castle Rushen was built with stone from this quarry 900 years ago.

SCOTCH MARBLES.

Quarry.	Nearest Station.	Nearest Port.	Colour.	Remarks.
Tiree	Oban, N. British and Caledonian Rly. Hebrides.	Scarinish, Tiree	White, pink, green, etc.	Block for bust of Sir W. de la Becke, Museum of Practical Geology.

WELSH MARBLES.

Quarry.	Nearest Station.	Nearest Port.	Colour.	Remarks.
Penmon	Menai Bridge, L. & N. W. Rly. Anglesea.	...	Mottled grey	For polished and decorative work; also in blocks sawn or rough for buildings, etc., and limestone (98·75 carb of lime) for fluxing and chemical purposes. Britannia Tubular Bridge, etc. Depth of bed, 15 ft.

IRISH MARBLES.

Quarry.	Nearest Station.	Nearest Port.	Colour.	Remarks.
Ballymore	Dunfanaghy Road, Donegal.	Dunfanaghy	White and blue	Polishes well, highly crystalline; difficult to work; chimney-pieces.
Clonmacnoise	Belmont or Ballinasloe, G. S. & W. Rly. King's County.	Dublin. It is carried from Shannon Bridge, which is $1\frac{1}{2}$ miles from quarry, to Dublin by canal.	Blue	A good dry limestone for building; takes a splendid polish, with beautiful fossils.
Firies	Castle Island, G. S. & W. Rly. Kerry.	Tralee	Red	Solid, sound stone, and will stand almost any weight; is easily dressed and takes a very good polish. It can be easily got in almost any size; depth of bed, 20 ft.
Kilkenny	Kilkenny, G. S. & W. Rly. Kilkenny.	...	Black	When dressed the figures of shells appear.
Mento	Galway, M. G. W. Rly. Galway.	Galway	Black	Best description of black marble. Good water carriage to Galway. There are three beds: the middle is called the "London bed," and exported; blocks 5 ft. to 10 ft. long and 4 ft. to 5 ft. wide, sawn on the spot into slabs, etc.
Tullamore	Tullamore, G. S. & W. Rly. King's County.	Dublin	White, slightly tinged with blue	This limestone takes a good polish; makes excellent lime; is capable of being worked to any shape; has no "crossway," that is, it works freely to the tools in any direction. Some varieties clouded; used for polished work, chimney-pieces, etc.

Chapter VIII.

LIMESTONE.

THE method of quarrying limestone necessarily varies considerably, as does the stone itself. Where, like the Keinton stone, it occurs near the surface as a homogeneous stone in thin, well-defined horizontal beds, having good natural joints, little more is needed than to lever it out with crowbars and lift it to the surface, the quarry being worked in floors rather than faces. The subsequent working is equally simple, being mostly done with the hammer, or with mallet and chisel, to produce an approximately fair face, machinery being little resorted to. The detritus can be crushed for road metal or burnt for lime, so that if the quarries were well situated for transport and the lime could be sold at a profit there would be little waste. This not being the case, the waste is considerable.

As a contrast to this, the various Bath stones are mined. They occur in deep beds, up to as much as 22 ft. in thickness, which rarely outcrop, but have to be reached by long inclined shafts sunk in the hill side. Pillars of hard stone of little value occur at intervals, and these are left to support a natural roof of hard rock, while the bed of freestone is removed. Between the freestone and the roof, at any rate in the Monk's Park quarry which was visited, there is a thin layer of rubbish, which is first removed with pickaxes, some of which have very long handles, enabling a depth of 5 ft. to be reached. This done, a vertical cut is made down the side, against the hard stone, with a long toothed hand-saw, held horizontally and worked with one hand. A second similar cut is made to form a V groove, wide enough for a man to squeeze into, the stone between

the two cuts having to be chipped out as waste if, as is usual, it will not come out solid. Then a man standing in the groove saws downwards at the back of the space picked out, and finally a third saw-cut separates the block, all these cuts being taken down to a natural joint. A roughly rectangular block is thus produced, almost free from waste, and this can be levered out and lifted by cranes on to trucks running on trolly lines through the mines to the foot of the shafts.

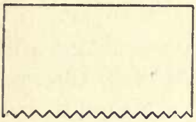


Fig. 26. Drag.

Bath stone, at least that from quarries owned by the Bath Stone firms, which is dislodged during the winter months, is kept in the underground workings till the spring, so as not to expose it to frost while the quarry sap is in it. When brought to the surface every block is tapped all over with a pebble. If it gives off a ringing sound, the block is a good one, but if the sound be dull a vent is indicated, and its position is then located and it is cut out before the block is sold.

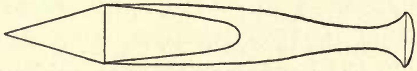


Fig. 27. Point.

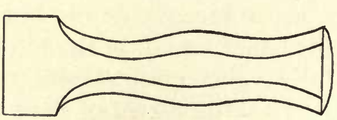


Fig. 28. Boaster.

There is scarcely any waste from a Bath stone quarry, especially as the "venty" blocks and the smaller pieces are squared and sold as holy-stones for cleaning ships' decks.

In the subsequent working of limestones, the circular, rocking, and hand saws are all used, with or without teeth, according to the hardness of the particular stone, sand washed in with water replacing the teeth when the toothless saw is used. Machinery is not often employed, at any rate for the oölites and dolomites which are soft enough to be profitably worked by hand, except in large works, where

a circular rotating rubbing bed of iron, on which the stone rests in sand and water, is used to remove saw marks and produce a plane surface. In smaller works, rubbing is done with a piece of sandstone by hand ; or else a plane face, or nearly so, is produced by scraping the surface with a thin metal comb known as a *drag* (see Fig. 26). Sinking, moulding, grooving, etc., are all performed with chisels, varying from the *point* to the *boaster* (Figs. 27 and 28), the latter having an edge 2 ins. wide or more, intermediate sizes alone being known as *chisels*. These names are, however, liable to local variation.

In many parts of the country there exist groups of small limestone quarries, little known beyond their own locality, but producing stone of excellent quality. Of these, the Rutland group may be taken as an example, comprising the Barnack, Ketton, and Casterton stones, whether "free" or "rag" (the rag-stones being shelly conglomerates), of which the Barnack Rag, of which many cathedrals and churches were built, is no longer procurable. The Casterton quarries, near Stamford, were inspected, and may be described as being typical of many other small quarries. They are open workings of no great depth, overlaid with fireclay, which is removed for burning into adamantine clinker, beneath which is a thin layer of useless stone above two beds of good freestone, composed of rounded grains cemented together by carbonate of lime, each with a maximum depth of 3 ft. 6 ins. When first quarried the stone is soft to work, and friable, but it acquires a hard surface on exposure, and weathers well, in a country district at any rate. The bedding is difficult to detect, but immaterial, as the stone may be laid equally well in any direction—a very useful quality for undercut moulding and carving. The colour varies from white through quiet shades of pink and buff, and the supply is limited to some 200,000 cubic feet per annum, the largest block obtainable containing about 80 cubic feet.

The following analyses of true limestones, dolomites, and

siliceous dolomites are instructive, bringing into strong contrast the distinguishing characteristics, chemically speaking, of these stones :—

Typical Stones.	Carbonate of Lime.	Carbonate of Magnesia.	Oxide of Iron and Alumina.	Silica.	Water.	Bitumen.
LIMESTONES.						
Weldon	94·35	...	0·89	0·08	1·13	...
Barnack	93·4	3·8	1·3	...	1·5	trace
Chilmark	79·0	3·7	2·0	10·4	4·2	trace
Ham Hill	79·3	5·2	8·3	...	2·5	trace
Mansfield	93·59	2·90	0·80	2·0	2·71	trace
Bath Box	94·52	2·50	1·20	...	1·78	trace
Portland...	95·16	1·20	0·50	1·20	1·94	trace
Ketton	92·17	4·10	0·90	...	2·83	trace
Kentish Rag (homogeneous)...	92·6	trace	7·00	...	...	0·4
DOLOMITES.						
Mansfield Woodhouse (Yellow)	51·65	42·60	...	3·70	2·5	...
Bolsover Moor	51·1	40·2	1·8	3·6	3·3	trace
Roach Abbey	57·5	39·4	0·7	0·8	1·6	...
Huddlestone	54·19	41·37	0·30	2·53	1·61	...
Park Moor	55·7	41·6	0·4	...	2·3	...
Newthorpe	55·4	43·53	0·36	0·71	trace	...
SILICEOUS DOLOMITES.						
White Mansfield	26·50	17·98	1·32	51·40	2·08	...
Red Mansfield	26·50	16·10	3·20	49·40	4·80	...

The three stones known as Mansfield, vary much both in colour and composition, while in other instances the stone from different beds of the same quarry are entirely distinct. It consequently happens that in any classification of limestones, the same name will sometimes occur in two different lists. There are so many varieties of limestone that they have to be distinguished in some way. Custom has based a nomenclature for them, rather irregularly, on their physical condition, mineral contents, and stratigraphical relation to other rocks, and sometimes on the three combined. Limestone can be crystalline or amorphous, compact or fissile; it may be pisolitic, oölitic, concretionary,

or shelly ; there are argillaceous, siliceous, bituminous, and dolomitic varieties ; others may be brecciate or coralline, whilst there is no end to the names they derive from their relation to other rocks in the sedimentary strata—it will be sufficient to mention the Silurian, Devonian, Carboniferous, Lias, and Tertiary limestones as examples of this class of names. Again, limestones are called after the localities in which they are found : these are Woolhope, Wenlock, Derbyshire, Bath, Portland, Purbeck, and Bembridge limestone, these local names being in some cases compounded with others, as for instance Bath oölite, Portland oölite, Wenlock concretionary, etc.

ENGLISH LIMESTONES.

Quarry.	Depth of Bed in ft.	Extreme Weight of Block in tons.	Station.	Port.	Crushing Resistance per super ft. in tons.	Weight per cubic ft. in lbs.	Colour.	Remarks.
Ancaster	...	...	Sleaford, G. N. Rly. Lincolnshire.	...	552·6	156·3	Brown	Compact shelly stone; becomes harder after being quarried, and weathers well.
Do.	...	...	Do.	...	184·0	140·4	Cream	Fine oölite, resembling Portland stone.
Ball's Green	3½	7	Nailsworth, Mid. Rly. Stroud, G. W. Rly. Gloucestershire.	Bristol	...	160	White	Churches, staircases, chimney pieces, altars, screens, reredos, fonts, tracery, windows, floors, etc. Known as Painswick stone; very uniform in grain. Used for Houses of Parliament, etc.
Beer	5	5	Seaton, L. & S. W. Rly. Devonshire.	...	162·1	140	Light brown	Admirably adapted both for the finest carving and for the ordinary requirements of ecclesiastical and domestic work. Cathedral and St. Peters, Exeter. Soft when first quarried, hard when seasoned.
Bolsover Moor	20	5	Chesterfield, Mid. Rly. Derbyshire.	...	...	179	Cream	Used at Welbeck Abbey and Southwell Minster; was selected for the Houses of Parliament, but the quarries could not produce the quantity required; used for paving, and burns into a good lime.
Bramham Moor	2½	5	Tadcaster, N. E. Rly. Yorkshire.	...	...	127·5	Light yellowish brown	Smawse Quarry and Bramham Moor Quarry are one and the same.
				BATH STONE.				
Box Ground	4	...	Corsham, G. W. Rly. Wiltshire.	...	97·5	127·9	Light brown	The stone from the quarries owned by the Bath Stone Co. are obtained from that formation known as the "Great" or "Lower Oölitic" group. Of medium grain; is suitable for sills, plinths, string courses.
Bradford	3½	...	Corsham, G. W. Ry. Wiltshire.	...	...	...	Light brown	A good weathering stone.

These comprise the Bath Stones.

Combe Down	4½	...	Corsham, G. W. Rly. Wiltshire.	...	117·7	128·6	Very light brown	A good weathering stone; tairly free-working.
Corngrit	4	...	Corsham, G. W. Rly. Wiltshire.	...	134·5	133·6	Light "stone" colour	A good, hard, strong stone.
Corsham Down	4	...	Corsham, G. W. Rly. Wiltshire.	...	94·5	123	Light "stone" colour	A fine-grained, even-textured, free-working stone.
Farleigh Down	4	...	Corsham, G. W. Rly. Wiltshire.	...	62·5	122·7	Warm cream	A fine, even-textured stone.
Monk's Park	4	...	Corsham, G. W. Rly. Wiltshire.	...	139·6	136·7	Light "stone" colour	A compact, close-grained, and very strong stone.
Stoke Ground	6		Corsham, G. W. Rly. Wiltshire.	...	90	126·3	Light brown	A good weathering stone of uniform texture.
West-wood Ground	6	...	Corsham, G. W. Rly. Wiltshire.	...	110·2	130·3	Light brown	A good, sound, close-textured stone.
Casterton	4	...	Stamford, Mid. Rly., G. N. Rly., L. & N. W. Rly. Rutland.	...	...	130	Warm cream, and sometimes tinted with pink	General building; used principally for mansion and ecclesiastical work, tracery, windows, etc., largely used in 15th, 16th, 17th and 18th centuries for church work; many examples to be seen at present time in good preservation known as Stamford marble; Ely Cathedral, buildings in Stamford.
Chil-mark	...	...	Salisbury. G. W., L. & S. W., M. & S. W., L. & N. W. Rlys. Wiltshire.	...	...	153·5	Light greenish grey	
Colly Weston	...	...	Colly Weston, Northamptonshire	...	...	...	...	
Doulting (Bramble Ditch and Chelynch)	...	...	...	...	...	...	...	

ENGLISH LIMESTONES—*continued.*

Quarry.	Depth of Bed in ft.	Extreme Weight of Block in tons.	Station.	Port.	Crushing Resistance per super ft. in tons.	Weight per cubic ft. in lbs.	Colour.	Remarks.
Dundry	6	...	Bristol, G. W., M., L. & N. W., Mid., & N. E. Rlys. Gloucestershire.	Bristol	...	140	Yellow	St. Mary's, Redcliffe; restoration of Bristol Cathedral, Llandaff Cathedral.
Ham Hill	...	...	...	...	...	133·7	Yellow	Contains pretty clay markings, does not weather well in towns.
Haydor	...	...	Grantham, G. N. Rly. Lincolnshire.	...	...	...	Brownish cream	Essential that this stone should be set upon its natural bed. Lincoln Cathedral; Boston, Grantham, Newark, and other churches; Culverthorpe House and Belvoir Castle.
Hildenley	4	...	Malton, N. E. Rly. Yorkshire.	...	...	130·6	Light grey	Very fine grain, more fit for fine carving than building; was used extensively by the monks for Kirkham Abbey, and Old Malton Abbey is built of it; resembles indurated chalk: used for paving; columns of chapel, Castle Howard.
Hopton Wood	...	...	Wirksworth, Mid. Rly Derbyshire.	...	444·4	158.4	White	Used for monumental work, landings, steps, slabs, and paving; takes a good polish; used in Imperial Institute, London.
Huddle-stone	...	...	Sherburn, N. E. Rly. Yorkshire.	...	...	137·8	Whitish cream	Hard veins occur in the stone; used for York Minster, the Cross opposite Charing Cross Station, etc.
Keinton	...	...	Somerton, G. W. Rly. Somersetshire.	...	...	...	Blue-grey	Used for paving, building, and lime.
Kentish Rag	...	...	Maidstone, S. E. & C. Rly. Kent.	...	...	166·6	Blue-grey or greenish grey	
Ketton	...	...	Ketton, L. & N. W. Rly. Rutlandshire.	...	101·7	128·3	Cream and pink.	Good durable stone, oölitic grains well defined: used for stairs, plinths, mullions, etc.; St. Pancras Station, Sandringham Hall, etc.

Ketton Rag	3	7	Ketton, Mid. Rly. Rutlandshire.	...	170	150	Warm cream	Largely used for monumental works; used at the Tower of London, St. Dunstan's Church, Fleet Street, York Minster, etc. The rag beds are white cemented with highly crystallized carbonate of lime. The crash is of a dark brown colour, very coarse, full of shells, distinct ova, and very ferruginous.
Mansfield	...	...	Woodhouse, G. C. Rly. Nottinghamshire.	...	577·4	145·4	Yellow	Magnesian limestone, resembling Bolsover Moor; used for carved work, mouldings, etc.
Newthorpe	...	...	South Milford, N. E. Rly. Yorkshire.	...	...	137·2	Cream	Lime for building purposes; subject to potholes containing calcareous spar. Used for Pontefract Old Church, Campsall Lodge, etc.
Painswick	...	...	Stroud, G. W. Rly. Gloucestershire.	...	...	...	Cream	Known as Painswick stone; very uniform in grain.
Pomphlet	80	100	Plymouth, G. W. and L. & S. W. Rlys., Devonshire.	Plymouth	58	168	...	Used for building purposes, also calcining for building and agricultural lime.
Portland: Whit bed Base bed	9 ft. 6 ft.	1	Portland, G. W. and L. & S. W. Rlys. Dorsetshire.	Portland	204·7 287·0	132·3 137·6	Brown White	The whit-bed is chiefly used for building purposes; the base-bed is used both for monumental and building purposes.
Portwash	...	...	Castletown, Isle of Man.	Castletown, Manx N. Rly.	...	...	Black	Is a so-called marble, but is really a fine block limestone; used for steps of St. Paul's Cathedral.
Presthope	180	...	Presthope, G. W. Rly. Shropshire.	...	...	...	Pink, grey and blue	For fluxing purposes, also for rockeries and monumental works.
Purbeck	...	...	Swanage, L. & S. W. Rly. Dorsetshire.	Swanage	...	...	Dark blue or grey	See Purbeck marble.
Smawse	2½	5	Tadcaster, N. E. Rly. Yorkshire.	...	...	127·5	Light yellowish brown	Crisp and brittle, not fit for steps. Ripon Minster; repairs York and Beverley Minsters. Hull Old Church, St. Mary's Church, Beverley.
Stone Ends, Anston	2½	...	Kiveton Park, G. N. Rly. Yorkshire.	...	301·9	150	Deep cream	Steps, landings, window-sills, mouldings, etc.; used in Houses of Parliament for plinths of building towards river.

ENGLISH LIMESTONES—*continued.*

Quarry.	Depth of Bed in ft.	Extreme Weight of Block in tons.	Station.	Port.	Crushing Resistance per super ft. in tons.	Weight per cubic ft. in lbs.	Colour.	Remarks.
Taynton, No. 1	6	10	Shipton-under-Wychwood and	Gloucester	150	140	Cream	Easily worked, and hardens on exposure; frost has very little effect upon it. Used at Magdalen College School, Indian Institute, Mansfield, and St. John's Colleges, Oxford, etc.
Taynton, No. 2	6½	10	Notgrove, G. W. Rly.	Gloucester	150	140	Warm cream	
Taynton, Guiting	6½	10	Notgrove, G. W. Rly. Gloucestershire.	Gloucester	150	140	Orange	
Tisbury	...	...	Salisbury, G. W., L. & S. W., M. & S. W. and L. & N. W. Rlys. Wiltshire.	...	...	...	Light greenish grey	
Tottern-hoe	...	...	Dunstable, L. & N. W. Rly. Bedfordshire.	...	...	...	Greenish white	Used for Dunstable Priory, Woburn Abbey, Luton and other churches.
Wardour	3	4	Tisbury, L. & S. W. Rly. Wiltshire.	...	136 6	130	Greenish brown	Chilmark stone.
Weldon	20	10	Weldon and Corby, Mid. Rly. Northampton-shire.	...	...	150	Rich creamy white	Oölite, saws freely without water; used for dressings and ashlar in ecclesiastical and public buildings and mansions. New University Library, Cambridge, Chapter House, Lincoln, restoration; Geddington Cross.
Wood-house	...	...	Mansfield, Mid. Rly. Nottingham-shire.	...	577·4	145·8	Cream, brown	Used for lower part of river front of Houses of Parliament, Southwell Church.

WELSH LIMESTONES.

Little Orme's Head.	...	...	Llandudno L. & N. W. Rly. Carnarvonshire.	...	...	...	...	The quarry is not worked for building stone; it is principally used for fluxing purposes.
Troeth-Cychan.	9	12	Llangefni. L. & N. W. Rly.	Dock at Quarries, Deganwy or Bangor	...	180	Light grey	Used for chapels, churches, sea-walls, bridges, locks, docks, monumental works, etc.; takes an excellent polish.

IRISH LIMESTONES.

Ballintogher	3	1	Lixnaw, G. S. & W. Rly Kerry.	...	...	112	Black, white, and dark grey	Used chiefly for lime burning.
Ballisodare	2	4	Ballisodare, G. S. & W. Rly. Sligo	Sligo	...	168	Dark blue (when rough), pale blue or white (when worked)	Stone very durable, rather hard to work; compact texture, works well. Victoria Bridge, Sligo.
Barley Hill	...	...	Carrickmacross, G. N. Rly. Monaghan.	Dundalk	...	...	Blue	Used exclusively for the manufacture of lime, which is of a light colour when burned.
Brachernagh	4	30	Ballinasloe, M. G. W. Rly. Galway.	Galway or Dublin	127·10	168	Whitish blue	Cathedral and monumental work.
Crossdrum	2	10	Oldcastle, G. N. Rly. Meath.	Castlecor and Dublin	...	...	White	Monumental and church work, works freely; can be obtained in large blocks.
Foynes	2½	10	Foynes, G. S. & W. Rly. Limerick.	Foynes	...	168	Grey and dark blue.	Is chiefly used for harbour work; bears a great pressure. Railway station, Foynes; Kildegrat piers. A good stone for engineering work.
Gilloque	28	...	Limerick, G. S. & W. Rly. Limerick.	Limerick	..	112	Rich blue-black	Capable of taking high polish, close nature; principally used for building purposes; yields a good hydraulic lime. Used at Floating Basin, Limerick Docks.

IRISH LIMESTONES—*continued.*

Quarry.	Depth of Bed in ft.	Extreme Weight of Block in tons.	Station.	Port.	Crushing Resistance per super ft. in tons.	Weight per cubic ft. in lbs.	Colour.	Remarks.
Gorestown	3	1½	Trew and Moy, G. N. Rly. Tyrone.	Moy	...	112	Blue	Very good lime, road metal, and building stone.
Kenmare	20	...	Kenmare, G. S. & W. Rly. Kerry.	Kenmare	...	...	Grey	Quarried for lime burning; slaty, hard to work. Used for suspension bridge.
Killarney	50	...	Killarney and Rathmore, G. S. & W. Rly. Kerry.	Cork and Tralee	...	...	Grey	Heavy crushing resistance; hard, even grained; difficult to work. Several quarries near Killarney, some yielding flags used for Muckross Abbey.
Kintogher	1½	3	Sligo, G. S. & W. Rly. Sligo.	Sligo	...	175	...	
Leixlip	1½	...	Leixlip, M. G. W. Rly. Kildare.	Leixlip	...	182	Black	Good for dressings; works easily, and presents a whitish colour when dressed.
Lissatonry	45	¾	Nenagh, G. S. & W. Rly. Limerick.	Limerick	...	...	Grey and blue	
Little Island	40	3	Queenstown Junction, G. S. & W. Rly. Cork.	Cork	...	265	Light grey.	Lime obtained from it at Glasgow. Used at Watchet in paper making. Used extensively in Government work, forts, Spike Island, etc. Very fossiliferous; works freely.
Magheramorne	150	...	Magheramorne	Magheramorne, Belfast and Northern Counties,	...	200	White	Very even in texture.
Shandon	36	...	Dungarvan, G. S. & W. Rly. Waterford.	Dungarvan	...	...	Light grey	

[illegible]	[illegible]	[illegible]	Skerries, G. N. Rly. Dublin.	Skerries	...	172	Grey	Close grained. Many public buildings in Dublin; all churches of every denomination within 20 miles of Skerries. Makes a splendid plastering lime.
Tullamore	...	...	Tullamore, G. S. & W. Rly. King's Co.	...	...	...	Blue	Good for dressings and monumental work.

FRENCH LIMESTONES.

Château-Gaillard	...	...	Poitiers	...	184	140	White	D'Orsay Paris, Gare du Midi, Bordeaux, etc. Very similar to Normandoux; used at Celestins Barracks, Palais de Tuileries, Paris, Hôtel de Ville, Poitiers, etc.
Liais Loup	...	...	...	...	320	172	White	Hard and highly fossiliferous, the fossils giving a spotted appearance; takes a polish.
Normandoux	...	...	...	...	262	154	White	Very fine close grain with a texture like chalk; works to a very smooth surface. Used at Gare d'Orleans, Paris.
Peuren	...	...	...	...	429	172	Cream	Very even grain; works to a smooth surface. Used at Palais de Justice, Tribunal de Commerce, Opéra Comique, etc., Paris.
Tabliere	...	...	...	...	320	172	Light yellowish brown	Coarse grain; works to smooth surface.

A FEW OF THE BETTER-KNOWN FRENCH LIMESTONES.

	Crushing Strength per square in.	Weight per cubic ft.
	lbs.	lbs.
Abrots	15589	162
Ancy-le-Franc	16410	162
Charentenay...	3418	143
Chassignelles	6836	150
Comblanchien	15042	175
Euville	4485	150
Larrys	4102	150
Larrys perlé	9572	156
Lignerolles	5470	150
Massangis (Liais)	9572	156
Massangis (Roche)	8888	156
	12005	162
Mazure-Dujon B. R.	1099	137
Mereuil	12367	156
Palotte Banc Franc (B. F.)	2735	131
Palotte Banc Royal (B. R.)	2050	124
Ravières	4102	150
Theuville B. R.	1367	112
Villars	15042	175

Chapter IX.

SANDSTONES.

SANDSTONES are all worked in open quarries, either by levering and wedging, where the lamination is thin and the beds distinct, or by blasting when the stone occurs in rock masses, the processes generally being very similar to those already described, and the thinner slabs of softer stone as a rule overlying the thicker blocks of compacted rock.

After quarrying, the stone is not only shaped to rough block, but is often completely worked up ready for fixing in position at the quarry side, where there are the proper machinery and workmen skilled in the manipulation of the particular stone produced, most of the sandstones being sufficiently hard to stand a railway journey after being worked without serious risk of being chipped in transit.

There is not much waste, as the chippings can be used as road metal, or crushed for concrete.

Sawing is accomplished either with circular saws (those with scupper-nail teeth and of large diameter being used where the blocks are thick, as are those of the Forest of Dean stone) or with toothless horizontal rocking blades, supplied with a mixture of water, lime, and chilled steel shot, the lime being required to remove rust stains caused by the steel blades.

Straight moulding is done mostly by machinery with plane irons, but face work, rounded mouldings, and mitres are worked by hand, the first for economy's sake and the last because a true mitre is difficult to make by machine.

One of the best sandstones in the country is that known as Blue Pennant, found at Fishponds, near Bristol, and principally owned by the Hard Stone Firms, Limited, in

G 2

accordance with a system of amalgamation of quarry owners which seems to be customary in that district. It is of a moderately deep blue colour, obtainable both as slabs up to 12ft. by 8ft. from the upper beds, and as blocks having a thickness of as much as 20ft., the sizes obtainable being only limited by the capacity of the lifting machinery. In every way it is an excel ent stone, hard, strong, coming to a fine surface, and weathering and wearing well; but its hardness makes it difficult to work, and it is consequently expensive. Hammer-dressed—locally known as "Polled Pennant"—it makes excellent "shoddies," or rough wall facing, while more highly worked it can be employed for all purposes for which stone is useful, for facing, quoins, sills, lintels, hearths, steps, landings, columns, and bed stones.

Very similar is the Forest of Dean stone—owned by another combination known as the Forest of Dean Stone Firms—of which there are many large quarries at Park End, Coleford, and other places, all in Gloucestershire. Not quite so hard as the Bristol Pennant, and consequently not so costly, it possesses the same good qualities of good face, wear and weathering, combined with large size, though the colour is scarcely so uniform, ranging from blue to grey; and the thicker blocks even if grey outside gradually change to blue in the centre, while the blue sometimes runs into brown. It is much used for girder beds and templates, monuments, steps and landings, and in bridge construction and dock work, all the ashlar and copings at Avonmouth Docks being of this stone, and all the stonework at Tidworth Barracks on Salisbury Plain.

Red Forest of Dean stone comes from Mitcheldean, on the borders of the Forest. This varies from a rich deep red, which is soft enough for general work, being not much harder than the blue from Coleford, to a very light red, which is nearly as hard as granite and almost too hard for mouldings and ornament, the colour and the hardness varying together. Layers of marl and stone alternate in the quarry.

The following are analyses of the Grey and Red Stones :—

Grey (Forest).		Red (Wilderness).	
Silica (partly free and partly combined...	80·16	Silica (quartz) ...	88·70
Alumina (combined with silica) ...	14·40	Alumina	3·25
Oxide of iron ...	1·65	Ferric oxide ...	1·80
Carbonate of lime	2·55	Ferrous oxide ...	0·30
Magnesia	0·24	Manganese oxide ...	0·10
Sulphate of lime ...	1·03	Lime	2·90
		Magnesia	0·11
		Carbonic acid ...	1·94
		Alkalies	0·31
		Loss...	0·59
	100·00		100·00

The Quarella stone, from Bridgend, in Glamorganshire, occurs in quite a small patch ; but it is a very good stone, and large blocks are obtainable. There are three distinct beds—one a beautiful light green suitable for general work, and very useful decoratively ; the second, known as "Ryder," varying in colour and only useful for cottage work ; and the third a very hard white stone obtainable in large blocks.

All the above, as well as the red sandstones of Cheshire, several of the Yorkshire stones, and the Scotch stones, both from the Dumfries and the Edinburgh (Craigleith) district, may be classed as General Building Stones. For practical purposes, the other principal classes of sandstones are the hard coarse-grained grit stones, suitable for engine beds and heavy engineering work, and the thin-bedded, laminated stones, used largely for paving slabs, steps and landings. Of both these classes there are large deposits in Yorkshire, and only smaller ones elsewhere, with the result that upon the London market the term "York Stone" has come to be considered as synonymous with "Sandstone," and includes many different varieties and qualities.

Another stone which demands special mention is that to which the trade name of "Shamrock" has been given, from Liscannor, in co. Clare, Ireland. It is a hard, clean grey mill-stone grit. The formation is peculiar. The stone is in enormous regular blocks, placed there as if by giant engineers of past ages, after being accurately sawn and planed. The top stone is without "bed." From this are made setts, kerbs, channelings, edgings, and blocks for dock and bridge work. The next stone below has a real but almost imperceptible bed. From this stratum are produced flags, landings, steps, etc. Without the bed, this stone could not have been available for use for pavements, as owing to its extraordinary strength and texture, there is no machinery in existence that could cleave or dress it. The bed of the stone is absolutely horizontal, without the slightest deviation, and thus it is comparatively easy to produce flags with true natural faces. The flags will always present an unbroken surface under any conditions, because the stone is so strongly knit together that the "bed," which fortunately allows the stone to be split, never becomes exposed by wear.

ANALYSIS OF SHAMROCK STONE.

Silica...	84·60
Alumina	6·60
Oxide of iron	3·60
Oxide of manganese	0·65
Lime	0·90
Magnesia	1·26
Sulphuric acid	trace.
Carbonic acid	nil.
Alkalies, &c.	0·39
Water	1·70
	100·00

The following are analyses of some of the best known Sandstones :—

—	Carbonate of Lime.	Carbonate of Magnesia.	Oxide of Iron and Alumina.	Silica.	Water.	Organic Matter.
Craigleith	1·1	...	0·6	98·3	...	...
Darley Dale	0·36	...	1·30	94·40	1·94	...
Heddon	0·8	...	2·3	95·1	1·8	...
Kenton	2·0	...	4·4	93·1	0·5	...
Caithness (Top Flag)... ...	10·93	6·16	10·21	68·40	0·42	3·88
„ (Middle Flag) ...	10·66	2·20	10·50	69·45	0·40	5·79
„ (Bottom Flag) ...	21·91	8·23	4·87	61·39	0·20	3·40
Dunmore (Bannockburn) ...	4·15	2·54	2·12	91·26	...	...
Corsehill	1·40	1·23	1·84	95·24	0·56	...

The information given in the following table has in every case been obtained by direct enquiry from the quarry owner, but it is always well, before deciding to use any particular stone, to obtain a sample and satisfy one's self that it is suitable for the purpose for which it is required.

ENGLISH SANDSTONES.

Quarry.	Extreme Depth of Bed in ft.	Port.	Station.	County.	Weight per cubic ft. in lbs.	Crushing Resistance per super ft. in tons.	Colour.	Remarks.
Ackworth	90	Hull and Liverpool	Ackworth, G. N. Rly.	Yorkshire	140·7	389·1	Brown and blue	Weathers well; suitable for copings.
Aislaby	...	Whitby	Whitby, N. E. Rly.	Yorkshire	132	70	Light yellow	Abbey and Docks, Whitby; University Library, Cambridge; Scarborough, and Bridlington Pie s.
Alton	5	...	Alton, N. S. Rly.	Stafford-shire	112	...	White and red	Good quality; yields large blocks similar to those used at Alton Towers.
Aspatria	3	Maryport, Cumberland	Aspatria, M. & C. Rly.	Cumberland	160	233·9	Red	Several quarries.
Bridge	12	...	Yorton, L. & N. W. Rly.	Shropshire	122·5	327	Red and white	All classes of building work; known as "Grinshl" stone.
Calverley Wood	24	Morley	Calverley and Rodney, Mid. Rly.	Yorkshire	172	...	Light brown	
Colley	6	...	Reigate, L. B. & S. C. Rly.	Surrey	103·1	...	Green	No longer quarried as a building stone; used as hearth-stone.
Cromford	100	...	Steeplehouse	Derbyshire	170	497	Pink	Very durable, and can be obtained in large blocks; mostly used for bridge, canal, dock, railway, and general engineering work.
Crossland Hill	30	...	Huddersfield, L. & N. W., L. & Y., G. N., and G. C. Rlys.	Yorkshire	155·2	...	Light brown	Weathers well.
Cunliffe	100	Preston	Blackburn, L. & Y., L. & N. W., and Mid. Rlys.	Lancashire	186	...	Light blue	Steps, landings, jambs, heads, sills, &c.; very durable.
Darley Dale or Stancliffe	200	...	Darley Dale, Mid. Rly.	Derbyshire	148·2	670	White	Abbey in Darley; Stancliffe Hall, Birmingham; Grammar School, Birmingham; and Nottingham Stations. Several quarries.

Quarries			well, Mid. Rly.	[illegible]	149	375	Grey	Penitentiary, Milbank; Victoria Docks, London; Birmingham and Leicester Gaols; Bridges on N. W. Rly.
Fishponds	8	Bristol	Fishponds, Mid. Rly.	Gloucestershire	175	1,001	Grey and blue	Called "Pennant Stone"; used for Philosophical Institute and Gaol at Bristol. A very durable stone.
Fletcher Bank	60	Ramsbottom	Ramsbottom, L. & Y. Rly.	Lancashire	168	...	White	Very durable and clean.
Forest of Dean	...	...	Coleford, G. W. Rly.	Gloucestershire	151·4	530	Grey and blue	An excellent wearing and weathering stone of large size.
Howler's Hill	...	...	Coleford, G. W. Rly.	Gloucestershire	155	...	Light grey and grey	Used for Cardiff and Newport Docks; some of the stone is blue.
Knockley	...	...	Coleford, G. W. Rly.	Gloucestershire	159·3	...	Grey	Used for Cardiff Pier.
Quarella	...	...	Bridgend, G. W. Rly.	Glamorganshire	...	...	Grey, green, and white	Green and white good for dressings, grey for landings; used for Colonial Institute, Landaff Cathedral, etc.
Viney Hill	...	...	Coleford, G. W. Rly.	Gloucestershire	155·7	...	Light purplish grey, with occasional light green spots	Used at Cardiff Pier, buildings in Gloucester.
Wilderness	...	...	Micheldean	Gloucestershire	...	...	Red	Speech House, Harrow; Quay Wall, Gloucester, etc.
Wimberry	...	...	Coleford, G. W. Rly.	Gloucestershire	...	...	...	Used in Newport and Cardiff; St. John's and Exeter Colleges, etc.
Gazeby	80	...	Shipley, G. N., Mid., and N. E. Rlys.	Yorkshire	150	575	Light brown and blue	Hard, good for steps; used for steps at British Museum, Town Hall. Bradford, etc.
Great Finsdale	18	...	Siding via Woodkirk, G. N. and L & Y. Rlys.	Yorkshire	168	...	Brown	Sills, landings, windows and doorheads, and wall stones. Can be had in large blocks; not hard, but very durable; good for dressings, stairs, etc.
Gunnerton	45	...	Barrasford, N. B. Rly.	Northumberland	140	354·6	Cream	
Hawkesworth	20	Hull, Manchester	Pool, N. E. Rly. Harsforth, N. E. Rly.	Yorkshire	160	550	Varies from light yellow to dark grey	Good weathering stone, becomes harder with exposure; close grained, similar to that from Spinkwell and Horsforth.

These comprise the Forest of Dean Stones.

ENGLISH SANDSTONES—*continued.*

Quarry.	Extreme Depth of Bed in ft.	Port.	Station.	County.	Weight per Cubic ft. in lbs.	Crushing Resistance per super ft. in tons.	Colour.	Remarks.
Hay	25	...	Kidderminster, G. W. Rly.	Shropshire	142	...	White and red	
Hipper-holme	...	...	Hipperholme, G. N. Rly.	Yorkshire				
Howley Park	...	...	Morley, G. N. Rly.	Yorkshire	160	...	Light brown	Very durable; used for dressings, stairs, etc.
Idle	...	...	Bradford, G. N., Mid., L. & Y., L. & N. W., N. E., N. B., G. C., G. W., L. & N. W., and G. E. Rlys.	Yorkshire	166 166 149·5	727·8 514·1 514	Light blue Light brown and Light yellow	Hard and durable; blocks, flags, landings; several quarries; stone used all over England, and also exported; paving at Guildhall and in many towns. The light yellow is similar to Bolton and Spinkwell stone, and will work in with them.
Kenton	...	...	Newcastle-on-Tyne, N. E., N. B., G. N., L. & N. W., Mid., Mid. & N. E., G. C., Lanc. & York.	Northum-berland	145·1	...	...	Used for New Town Hall in Newcastle-on-Tyne.
Long-ridge	90	Preston	Longridge, L. & N. W. & L. & Y. Rlys.	Lancashire	180	...	Brown and blue	A very durable stone, and is similar in texture to Darley Dale stone. Used for Royal Bank, Liverpool; most of the buildings in Preston.
Long-wood Edge	60	...	Longwood, L. & N. W. Rly.	Yorkshire	172	...	White and light blue	Flags, landings, etc.
Mansfield (Red)	8	Hull, Grimsby, Liverpool, or Manchester	Mansfield, Mid. Rly.	...	143·2	591·9	Roseate brown	Used for church paving, etc.

Mansfield (White)	8	Hull, Grimsby, Liverpool, or Manchester	Mansfield, Mid. Rly.	...	140·1	461·7	Greyish white	A good stone for landings and steps.
New-biggin	2	Silloth	Cumwhinton, Mid. Rly.	Cumberland	160	...	Red	Weatheral Railway Bridge
Penkridge	16	...	Penkridge, L. & N. W. Rly.	Stafford-shire	150	...	Red and grey mingled	West Front, Lichfield Cathedral; County Court, Walsall; and sundry churches
Robin Hood	...	...	Wakefield, G. N., Mid., L. & Y., L. & N. W., G. C., G. W. Rlys.	Yorkshire	...	595 3	Greenish grey	Landings, steps, and sawn slabs.
Runcorn	...	...	Runcorn, L. & N. W.	Cheshire	129·3	...	Dark red	Good stone; used for Liverpool docks.
Scotgate Ash	60	...	Pateley Bridge, N. E. Rly.	Yorkshire	160	734·3	Light brown	Chiefly used for landings, steps, headstones. heads, copings, sinks, etc.; called Delph Stone.
Shipley	80	...	Shipley, G. N., Mid. & N. E. Rlys.	Yorkshire	150	600	Light brown	Blocks, landings, etc.
Shorrock	30	Liverpool or Preston	Blackburn, L. & Y., L. & N. W., Mid. Rlys.	Lancashire	160	...	Brown and blue	Steps, copings, etc.
South Owram	17	...	Elland, L. & Y., Brighouse, L. & Y., Halifax, L. & Y. Rly.	Yorkshire	148	1,200	Grey	Used for steps, landings, etc.; much of the stone known as "York Stone" in the London market comes from this quarry.
White Freestone	90	Bromborough Pool, an offshoot of the Mersey	Spital, L. & N. W. & G. W., Birkenhead and Chester, L. & N. W., G. W. Rlys.	Cheshire	173	...	White	
Thorn-tons	...	Goole, Hull and Liverpool	Halifax, Brighouse, Bradford, Thornton, L. & Y. Rly.	Yorkshire	187	900	Blue and grey	Heads, sills, steps, landings, etc.
West End	90	...	Oxenhope, Mid. Rly.	Yorkshire	186	...	Light brown	Landings, etc.; shows lamination slightly, but very close and solid.

ENGLISH SANDSTONES—*continued*.

Quarry.	Extreme Depth of Bed in ft.	Port.	Station	County.	Weight per Cubic ft. in lbs.	Crushing Resistance per super ft. in tons.	Colour.	Remarks.
Whitby	...	Whitby	Whitby, N. E. Rly.	Yorkshire	132	70	Light yellow	Whitby Abbey; Lewisham Church New Library, Cambridge, etc.
Wideopen Sharp Grit	60	Newcastle	Killingworth, N. E. Rly.	Northumland	140	...	Light brown	Glass and blast furnaces, building stones, grindstones. Free stone, sharp grit.
Windy Nook	30	Shipped on the Tyne	Felling, N. E. Rly.	Durham	160	...	Yellow	

SCOTCH SANDSTONES.

Achscrabster	9	Thurso	Thurso, Highland Rly.	Caithness-shire	160	...	Blue	Weathers very well; good for external paving; very great transverse strength, being nearly twice that of Arbroath and three times that of Craigleith. Bituminous schist.
Bothwell Park	104	Glasgow	Fallside, Caledonian Rly.	Lanarkshire	134·5	...	Red	Stones supplied up to 10 tons and up to 5 ft. thick in natural bed.
Castlehill	12	Castlehill	Thurso, Highland Rly.	Caithness-shire	160	...	Blue	Weathers very well, good for external paving; very great transverse strength, being nearly twice that of Arbroath and three times that of Craigleith. Bituminous schist.
Corncockle	3	...	Nethercleugh, Caledonian Rly.	Dumfries-shire	152	383·8	Red	Free, easy working stone; blocks up to 90 and 100 cubic ft.
Corsehill	6	Annan	Corsehill siding	Dumfries-shire	154	635·9	Red	Close grained and weathers well. St. James's Hall, Piccadilly; Children's Hospital, Great Ormond Street; St. George's Hospital; Town Hall, Reading, etc.

Cove	120	Annan	Cove Quarry siding, Kirkpatrick, Caledonian Rly.	Dumfries-shire	135	650	Red	Used in New Technical College, and Stobhill Hospital, Glasgow.
Craigleith (or its modern substitute, Hailes Stone)	3	Leith	Craigleith, Caledonian Rly.	Edinburgh	165	339	Grey	One of the best sandstones in the country; quartz grains, siliceous cement, plates of mica; 98 per cent. silica, only 1 per cent. carbonate of lime; very hard and durable; good for ashlar and all building purposes. Used for nearly all the principal buildings in Edinburgh; also for piers of Southwark Bridge and many buildings in London.
Dunmore	10	Grangemouth	Plean Junction, Caledonian Rly.	Stirling-shire	143	435·5	White and a warm coloured brown	A good weathering stone. Much used in Glasgow and other large towns.
Duntrune	...	Dundee	Gagie Siding	Forfarshire	170	1,024	Blue	Used principally for stairs, steps, landings, and flagging.
Hailes Stone (see Craigleith above)								
Holburn Head	5	Thurso	Thurso, Highland Rly.	Caithness-shire	160	...	Blue	Weathers very well; good for external paving; very great transverse strength, being nearly twice that of Arbroath and three times that of Craigleith; Bituminous schist.
Hunter's Hill.	60	Glasgow	Bishopbriggs, N. B. Rly.	Lanark	186	...	White	A soft sandstone; fine grit. Much used for all the principal buildings in Glasgow and the neighbourhood.
Knockerra	Flag bed, 20 Block bed 15	Kilrush	Kilrush, W. Clare Rly.	Clare	140	...	Bluish grey	A freestone, used also for setts.
Leysmill	30	Arbroath	Leysmill, Dundee and Arbroath Joint, Caledonian, & N. B. Rlys.	Forfarshire	170	...	Yellowish grey	
Munlochy	$2\frac{1}{2}$	Fortrose	Munlochy, Highland Rly.	Ross-shire	160·6	...	White and red	Blocks, Cathedral Church of Ross at Fortrose; Inverness old bridge; Cromwell Court; also for canals, etc.

SCOTCH SANDSTONES—*continued.*

Quarry.	Extreme Depth of Bed in ft.	Port.	Station.	County.	Weight per Cubic ft. in lbs.	Crushing Resistance per super ft. in tons.	Colour.	Remarks.
Pyotdykes	3	Dundee	Lockee (West), Caledonian Rly.	Forfarshire	170	860	Blue	A good stone for stairs and landings. Used for Dundee Waterworks.
Slade	2	Arbroath	Carmyllie, Dundee and Arbroath Joint Rly.	Forfarshire	170	558·1	Blue	Used for landings, steps, pavements, hearths, etc.
Spittal	10	Thurso	Thurso, Highland Rly.	Caithness-shire	160	...	Blue	Weathers very well; good for external paving; very great transverse strength, being nearly twice that of Arbroath, and three times that of Craigleith. Bituminous schist.
Wellbank	...	Arbroath or Dundee	Wellbank siding	Forfarshire	170	...	Blue	Used principally for stair steps, landings, etc.
Westhall	...	Dundee	Gagie siding	Forfarshire	170	...	Grey	Used principally for building purposes, but is also suitable for stair steps, etc.
White "Hailes"	200	...	Kingsknowe, Caledonian Rly.	Edinburgh	143·8	662	White	Used extensively in Edinburgh: St. Mary's Cathedral, Observatory, etc.

WELSH SANDSTONES.

Abercarne and Newbridge	70	Newport	Newbridge, G. W. Rly.	Monmouthshire	67	...	Blue	Old churches and buildings in vicinity; Cardiff and Newport Docks. Similar to the Blue Pennant.

Ballyvoy	5	Ballycastle	Ballycastle, Ballycastle Rly.	Antrim	140	...	Pink	Blocks.
Caher-barna	32	Liscannor	Lahinch	Clare	160	...	Bluish grey	
Cronogort	15	Liscannor	Lahinch	Clare	172	2,214·5	Bluish grey	Channels, flags, landings, steps, etc.; very hard.
Doona-gore	15	Liscannor	Lahinch.	Clare	172	2,214·5	Bluish grey	Landings, steps, channels, flags; very hard.
Drum-keelan	3	Mount Charles	Mount Charles, Donegal Rly.	Donegal	154	50	White	Works well; wears well. All dimensions obtainable.
Faraba	12	Sligo	Glenfarne, S. L. & N. Co. Rly.	Sligo	160	...	White	
See Finn	10	Annalong	...	Down	140	...	Grey	Used for setts.
Watson-stone	...	Liscannor	Liscannor.	Clare	174	1,711·8	...	Used for paving blocks for docks and bridge works.
Youghal	200	Youghal	Youghal, G. S. & W. Rly.	...	...	...	Red and green	Laminated blocks.

Chapter X.

BITUMEN AND ASPHALT.

BITUMEN, or natural pitch, though limited for its commercial supply to a few districts, is nevertheless by no means of local or limited occurrence. Its origin is somewhat obscure, but it is probably the result of oxidation of the unsaturated hydrocarbons in petroleum.

Its specific gravity is 1·0924 and it is partially soluble in alcohol and more completely soluble in carbon bi-sulphide, petroleum spirit, chloroform, oil of turpentine, coal-tar, benzol and naphtha.

The great reservoir for natural bitumen, commercially, is the Pitch Lake of Trinidad, which seems to be inexhaustible, though it is only about 100 acres in extent. Much of it is used for laying pavements, for damp-coursing, cellar or basement flooring, flat-roofing, bridge-building (both for water-proofing and traffic), and to stop vibration in engine foundations, culverts, tunnels and subways. Electricians find it the best and most effective insulator known. It is elastic (in the popular sense), and is used in various circumstances where rigid cements fail, and wherever allowance has to be made for expansion and contraction. It is also employed in the manufacture of marine glue, and in its most highly refined state is made into wafers for fastening the tips on billiard cues.

All the well-known asphalt firms employ bitumen for purposes for which their own rock asphalt is not so well suited, sometimes alone and sometimes mixed with asphalt rock or grit.

Besides the Trinidad lake, there is a similar lake in Texas, at present not very accessible, while bitumen is

also found in great abundance on the shores of the Dead Sea in Judea, in Cuba, and in New Grenada.

Bitumen, according to Boussingault, on analysis is found to be made up as follows :—

Carbon	85
Hydrogen	12
Oxygen	3
	100

COMPOSITION OF TRINIDAD PITCH.

Volatile organic matter	76·75
Non-volatile organic matter	17·77
Ash	5·48

CHEMICAL COMPOSITION OF BITUMEN OF JUDEA.

Carbon	77·84
Hydrogen	8·93
Oxygen	11·54
Nitrogen	1·70
Sulphur	3·00

Of late years bituminous sheets have been made (by Messrs. Callender & Co.), by running refined bitumen on to paper bagging, which are capable of being bent in any direction without cracking and yet can be perfectly joined and are impervious to moisture. This material is now very largely used as a damp-course, and also for lining ponds and tanks, for covering arches, and between the inner and outer rings of brick sewers. It is made in various thicknesses, from $\frac{1}{8}$ in. upwards.

A modification of this, made by Messrs. Höfler & Co., consists of two layers of bitumen sandwiching a thin sheet of " laminated lead " between them. It is acid proof, and can be cut with a knife and bent in any direction ; and is

made in 6 ft. lengths and all standard breadths, from $\frac{1}{8}$ in. thick upwards.

An artificial rock asphalt is much used for street paving in the United States, consisting of

Trinidad bitumen	12·38
Organic matter	0·65
Mineral matter, sand, and other aggregate...	86·97
	100·00

This, it is claimed, is better than the natural rock, as the addition of the sand makes it less slippery.

ROCK ASPHALT, used for carriage-ways in Europe, is a natural limestone impregnated with natural bitumen. The rock when quarried is of a chocolate colour, fine in grain, thoroughly and evenly impregnated with bitumen, varying from 6 per cent. of bitumen and 94 per cent. of pure limestone to 14 per cent. of bitumen and 86 per cent. of limestone.

This is found principally in the Val de Travers (Switzerland), Laubsann (Alsace), Seysell (Ain, France), Montrotier Seyssel (Haute Savoie, France), Maestu (Spain), Ragusa (Sicily), and Limmer (Hanover) ; but the name of the company supplying it is not always much guide as to its place of origin, the Limmer Co., for instance, having quarries at Ragusa and at Montrotier Seyssel as well as at Limmer; while on the other hand, unless the name of a well-known company be specified explicitly, inferior asphalt from the same district, legally and correctly, say, Seyssel or Limmer asphalt, may be supplied and no redress be possible.

The following information, taken from a paper by Mr. Allan Greenwell, explains the matter very fully :—

"The method of obtaining this bituminous limestone or rock asphalt is by mining, and the seams are of varying thicknesses from very narrow streaks to 6 ft. and 10 ft. deep.

It is found between two layers of white hard limestone either totally unimpregnated with bitumen or else with mere traces of it, which have the appearance of thin smoke or the faint stains in white marble. Sometimes, however, layers of sand and marl are found which have to be propped or held up by rubble. The workings of the Fonticelle Mine in Italy, the property of the Neuchatel Asphalt Co., Limited, are subterranean ; from this mine comes the famous Val de Travers brand of asphalt.

COMPOSITION OF ROCK ASPHALTS (DURANT CLAYE).

—	Val de Travers (Switz.).	Laubsann (Alsace).	Seyssel (Ain, France).	Maestu (Spain).	Ragusa (Sicily).
Water and volatile matter	0·35	3·40	0·40	0·40	0·80
Bituminous matter ...	8·70	11·90	9·10	8·80	8·85
Sulphur (free or in organic combn.)	0·08	4·99	...	trace	...
Iron pyrites	0·21	4·44	...	...	...
Alumina and iron oxide ...	0·30	1·25	0·05	4·35	0·90
Magnesia	0·10	0·15	0·05	3·85	0·45
Lime	49·50	38·90	50·50	5·70	49·00
Carbonic acid	40·16	31·92	39·80	8·15	39·40
Combined silica	...	...	...	11·35	...
Sand	0·60	3·05	0·10	57·40	0·60
	100·00	100·00	100·00	100·00	100·00

"At the company's works the rock is treated so as to be formed into COMPRESSED ASPHALT (or COMPRIME) and MASTIC, the two forms in which it is used for the formation of roadways and pavements. For the purposes of the manufacture of the compressed asphalt the rock is received from the mines in blocks of irregular shape, which are first subjected to a crushing process in a steam crusher and broken to the size of walnuts. The material is then passed on to a machine called a disintegrator, which reduces it to powder. The powder issuing from the disintegrator is received on an inclined screen which allows the fine powder to drop through, while any grains too large for the meshes are

carried over and conveyed back to the disintegrator to be re-ground. The powder thus obtained is deposited in a covered shed; when required for use it is heated in slowly-rotating cylinders (very much like a large coffee roaster) over a fire of wood or coal until it reaches the right temperature for laying; this process takes two or three hours. The object of heating is twofold: (1) to evaporate moisture, (2) to bring the bitumen into such a condition that it may exert the maximum of binding power when subjected to compression by the rammers. If any portion is overheated the bitumen is fused; if underheated, the asphalt will not be thoroughly consolidated; hence the utmost care is needed in regulating the temperature, which varies for different kinds of asphalt, since some asphalts will bear a greater heat than others without deteriorating. The extreme limits are, say, 250 to 300 degrees F.

"The mastic, which is supplied in blocks, known as Val de Travers or other mastic, is manufactured by pulverising the natural rock in exactly the same manner as for the compressed asphalt; it is then heated in boilers, and from 5 to 10 per cent. of refined bitumen is added, and the whole mass reduced to a mastic or thick liquid state. This is run into moulds, and when cool again consolidates into a hard elastic block, which is used in varying proportions with grit and refined bitumen for laying pavements.

"In the laying of roadways with the comprime the method adopted is as follows:—The roadway is formed with a bed of good Portland cement concrete, and evenly finished off to the precise contour of the roadway required. When this concrete has become thoroughly set, and become hard and dry, the powder, which has been previously cooked, is brought to the site whilst hot; and as asphalt in bulk retains the heat undiminished for several hours it can be easily conveyed in properly constructed carts from the cookers to the site, where it is spread and raked over to a uniform thickness, usually two-fifths to three-fifths more than the depth of asphalt prescribed for the finished road.

The compression of the powder thus spread is effected by men with iron rammers, which have been previously heated in a fire to about the same temperature as the asphalt powder. After this has been accomplished and the mass reduced down to the finished thickness, the final smoothing is done by an iron instrument of curved form heated to an extent sufficient to soften the bitumen at the surface of the asphalt, and thus gives a fine finish and a glassy appearance to the whole. The work is then complete, and as soon as it is cooled to the temperature of the atmosphere the road can be thrown open to traffic. It can easily be seen that the whole operation of laying is one that calls for much special skill and practical dexterity for its efficient performance. Roadways thus formed are very good, being nearly noiseless, cleanly, and impermeable to moisture. They also diminish to the utmost the force required for traction, and are durable; but constant traffic is necessary to keep the asphalt compacted, and it is consequently unsuited in this form for roofs, gutters, and many other building purposes.

"In the laying of the mastic quite a different process is required. The mastic cakes, which are hexagonal, are manufactured at the works at Travers, and sent in this form to the site to be covered. These blocks are broken into pieces as big as a man's fist, ready to be thrown when required into the heating apparatus in which the mastic is cooked. This apparatus, commonly called a street pot, consists of two parts. There is first the mantle, a round envelope of sheet iron furnished with a chimney and a small door opposite it for firing, the upper and lower rims being strengthened with iron bands; and this frame forms the furnace in which the fire is kindled. The second part is the kettle proper, a round pot of strong iron with a steel bottom, destined to receive the mastic; this pot hangs on the upper rim of the mantle by the flange, descending into the furnace for a little more than half its depth, but high enough to allow the flames of the fire to play all round it. The best fuel for heating the whole surface of the pot, thus

giving uniformity to the melting, is peat or hardwood. Sometimes coke is used, but it should be avoided if possible, as it is apt to burn the bottom of the pot and thus tends also to burn the bottom mastic.

"Before lighting the fire a small piece of bitumen (half the required proportion) should be placed in the bottom of the pot, and, as soon as the fire has been lighted, the broken pieces of mastic placed on the top of it until the pot is a little more than half full; the cover should then be put over the top and the mastic allowed to stand for twenty minutes to half an hour, the fire being well kept up. During this time the materials should be watched, and as soon as the mastic commences to melt the cover should be removed and the mass stirred with a long stirrer.

"This stirring process finished, the remainder of the mastic should be put in, followed by half the remainder of the bitumen, filling the kettle to the top; again the cover should be put on and a steady fire kept up. When the mastic round the edges gives signs of melting it should be stirred constantly; when the whole mass has become pasty and soft, half the required proportion of fine sharp grit should be added with the remainder of the bitumen, spreading the grit evenly over the top.

"The proportion of materials generally used in cooking the mastic are as follows:—

Twelve blocks of mastic, say	640 lbs.
Refined bitumen...	39 „
Sharp grit (free from loam)	335 „

"The proportion of grit should be varied according to the aspect of the street where the mastic has to be laid. Where it is exposed to the heat of the sun for any considerable portion of the day more grit and less bitumen should be used in mixing. It is an indication that the material is cooked when jets of blue-coloured smoke ascend from the surface; another and most frequent test is that of thrusting a stick into the mass, and if it comes out clean and the

mastic does not adhere to it, the material may be considered cooked. This cooking process takes from four to six hours.

"The material being ready for spreading, the mastic is taken out of the pot and put into a wooden pail, which is passed to the man who is termed the spreader, and he empties the contents with a sweeping motion across the path. He then spreads the material with a wooden float to the required thickness. (For illustrations of the utensils

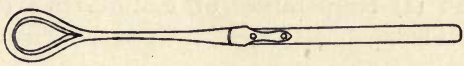


Fig. 30.

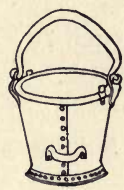


Fig. 31.

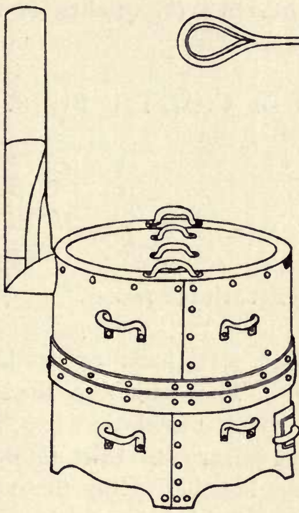


Fig. 29.

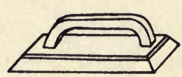


Fig. 32.

see Figs. 29, 30, 31, and 32.) It is essential in putting down this material that the second pailful should overlap the first whilst hot, and so on with each successive layer. If the surface on which the mastic is laid is at all damp, blisters will form in the mastic, and it is the business of the man who follows the spreader to prick them with a sharp piece of wood and rub the holes made until the blisters disappear. Sometimes he will also come across a burnt piece of mastic (caused by imperfect or insufficient stirring); this must be thrown out at once and hot mastic rubbed into the hole."

It will be again noted that in this mastic a great deal depends upon the method of preparation and laying and the quality of the bitumen used, as any omission of care and skill will render the asphalt when laid inferior and not able to fulfil its purpose.

COAL-TAR PITCH is the residue of coal-tar after the separation of naphthas, phenols, creosote and anthracene oils. It amounts to about two-thirds the original weight of the coal-tar before distillation. Its character varies with (1) temperature of distillation ; (2) quality of coal distilled.

CHEMICAL COMPOSITION OF COAL-TAR PITCH.

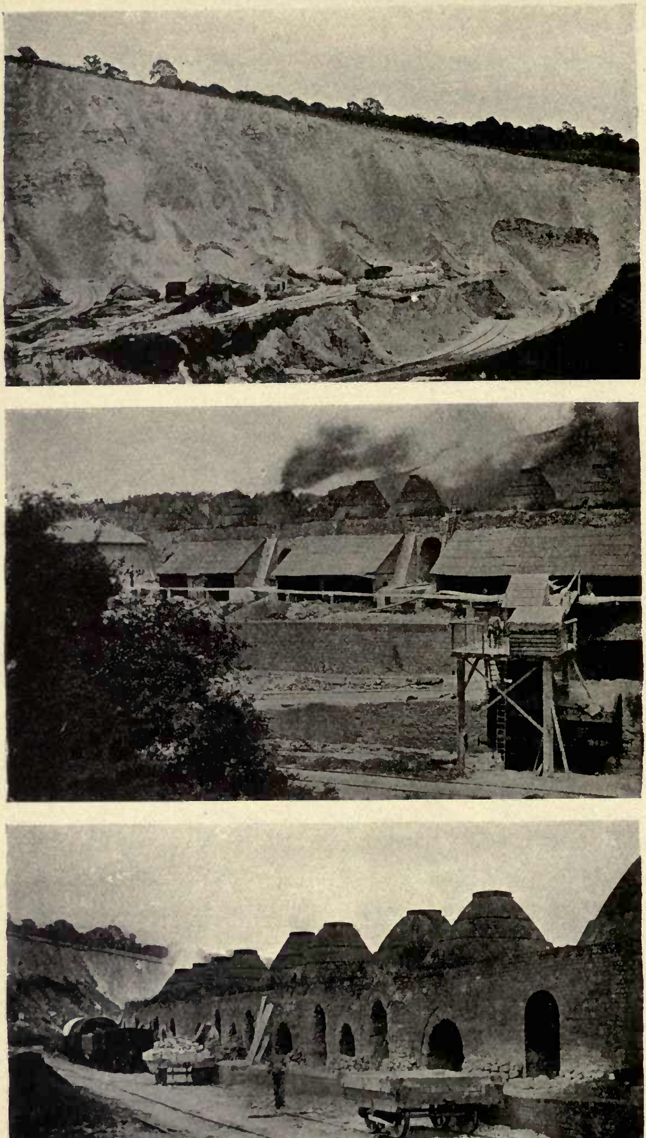
Carbon	75·32
Hydrogen	8·19
Oxygen	16·06
Ash	0·43

Sulphur and Nitrogen variable traces.

Coal-tar pitch may be either soft, hard or medium, according to quality of coal. The hardness depends greatly on the perfection to which distillation has been carried, and it is generally necessary to thin it down before use by addition of various tar oils. Only the heavy oils should be used, or the pitch will lose much of its binding or cementing power. It is obvious, therefore, that artificial pitch is not to be relied upon to the same extent as the natural product. It is, however, largely used for foot pavements to withstand moderate traffic, as the matrix of a kind of concrete, having coarse grit for an aggregate, and generally sprinkled over the surface either with marble chippings or crushed shells, the whole being laid hot and rolled with light rollers.

This is commonly known as "tar-paving," though it is pitch, and not tar, which is used.

PLATE IV.



MERSTHAM LIME WORKS.

General View of Quarry.—Front and Back View of Kilns.

[To face p. 105.

Chapter XI.

LIME AND LIME-BURNING—SOME MINOR LIME PRODUCTS: WHITEWASH, WHITING, PUTTY.

LIME, or quicklime, is a more or less impure oxide of calcium (CaO) obtained by heating limestone, chalk, shells, coral, or any other substance composed almost entirely of calcium carbonate ($CaCO_3$) in such a position, generally in the open air, that the carbonic acid gas (CO_2) and any moisture which it contains are given off and escape. This operation is known as burning or calcining, the chemical changes, neglecting those due to the presence of impurities, being represented by the equation

$$CaCo_3 + \text{heat} = CaO + CO_2.$$

The process of calcining is accomplished in kilns, of which there are two principal varieties. Pure chalk lime whose colour it is important to preserve is burnt in intermittent flare kilns (see Fig. 33) in such a way that only the flame from the furnace reaches the stone, which is piled up above the fuel over rough limestone arches; but much more frequently tall, inverted, cone-shaped draw-kilns (see Fig. 34) are used, the fuel (coal) and stone being piled up in them in alternate layers and worked to a roughly formed cone on top. Such a kiln is generally built on a hillside, so that it can be filled from the top (which is quite open) and emptied from the draw-hole at the bottom when burnt through, the average time taken in burning being about a week. When the fire has burnt out and the lime is cool enough for handling, the furnace bars are removed and the contents of the kiln fall down to

the draw-hole, whence they are at once carried in barrows into a shed—to be either sold in lump or ground to powder.

The lime generally used for mortar in the London district

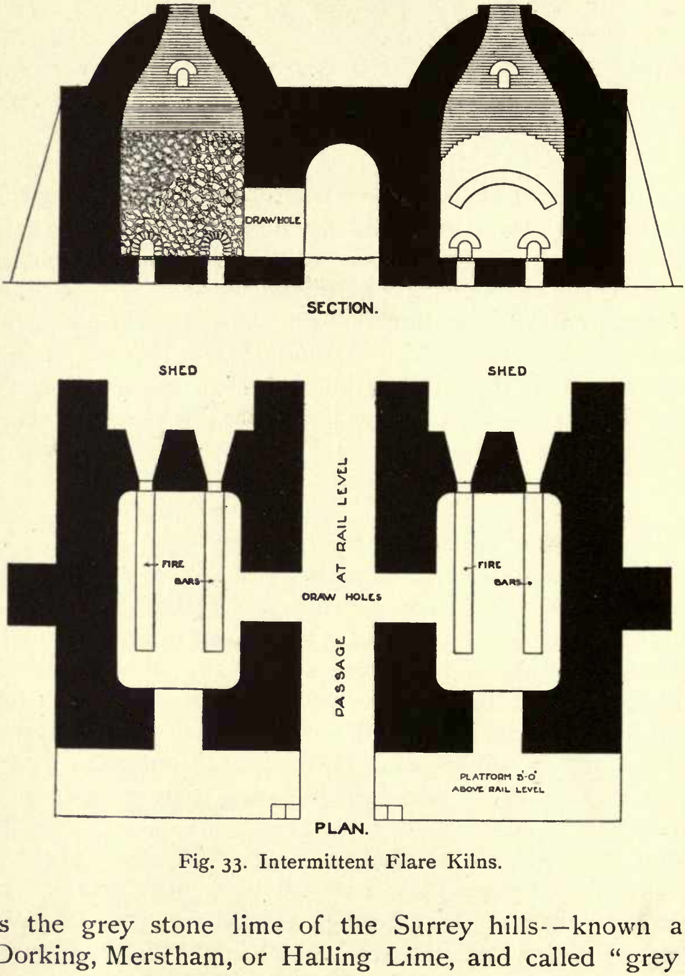
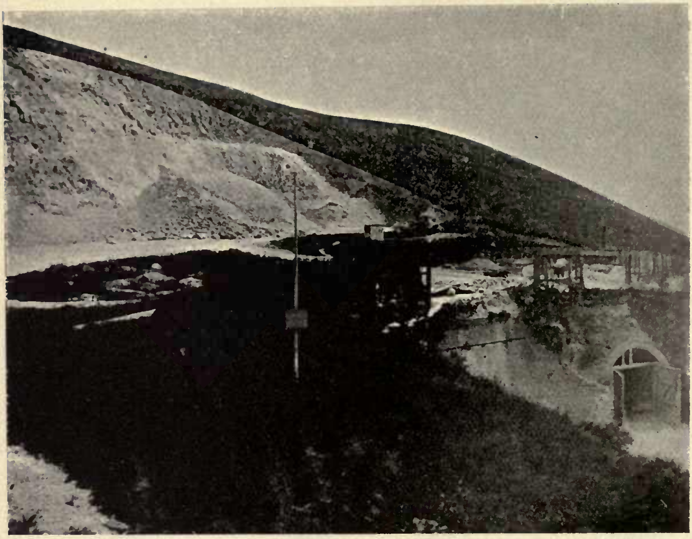


Fig. 33. Intermittent Flare Kilns.

is the grey stone lime of the Surrey hills—known as Dorking, Merstham, or Halling Lime, and called "grey" from the colour of the stone from which it is burnt, as after calcination it turns yellow. It is a mildly hydraulic lime,



General View.

Top View.

LIME QUARRY AND DRAW-KILN NEAR FOLKESTONE.

[To face p. 107.

suitable for rapid work, which acquires a moderate degree of hardness in course of time. At the Merstham works of Mr. Peters, the grey stone underlies the white chalk lime, and both are burnt in flare kilns separately. The kilns are filled from a high level door at the back on the hillside, which is closed with rough stones as soon as they are full, and firing takes place from a low level in front. The fires are at first kept low so as not to crack the arches of raw stone directly over them; but as these stones become hot more small coal is shovelled on, and the fires kept burning briskly till the whole kilnful is well burnt, when they are allowed to cool gradually. The whole process occupies about seventy-five hours. The burnt lime is removed from low-level draw-holes at the side, and at once filled into trucks for removal, or ground. Well-burnt lumps should ring well when tapped or hit together; and those of "stone lime" should be of a bright canary colour, the chalk lime remaining white.

Fig. 34. Inverted Cone Shaped Draw-Kiln.

Pure quicklime has a great affinity for water, and is extremely caustic, rapidly burning up and entirely destroying any organic matter with which it may come in contact. It is consequently much used as a disinfectant, being freely sprinkled over or dug into the contents of old cesspools or midden pits if such are met with in building operations.

If water be added to quicklime it "slakes"—that is, it absorbs the water with effervescence, giving out heat, and, if in lump form, tumbles to a fine powder. The caustic properties have been lost and the substance converted into

hydrate of lime ($Ca(HO)_2$), generally known as "slaked lime," as represented by the equation

$$CaO + H_2O = Ca(HO)_2.$$

Pure slaked lime, known as Rich Lime, has very little strength, and is mostly useful for whitewash and as a base for distemper. It will harden on the surface in course of time by absorbing CO_2 from the air, but if used in bulk or as mortar will remain soft underneath the hardened skin, and it has no cementing value.

If the lime contain sand only, no improvement is effected other than would be obtained by the addition of sand. It is rendered more pervious to air, so that the hard skin is deeper. Such a lime is known as a Poor Lime, and is rarely burnt.

Other impurities, however, notably clay and to a lesser extent magnesia (MgO) and oxide of iron (Fe_2O_3), affect lime most advantageously by their presence. They reduce the slaking action, rendering it slower at the same time; the extent to which the impurities are present being well indicated in this way. They also, according to the extent to which they are present, confer upon the lime the property of setting—that is, of contemporaneously hardening and coagulating, cementing together substances with which it is in proximity. This action, especially in the less pure varieties, seems to be cumulative, increasing slowly for a very long and at present undetermined period of time, and in such cases is better displayed under water than in air. Limes which show these characteristics are called Hydraulic Limes—either "Feebly," "Moderately," or "Eminently," according to the degree to which they appear. As a general rule limes burnt from chalk (known as CHALK LIMES) are only feebly hydraulic, and are suitable for plaster work only; those from ordinary limestone (known as STONE LIMES) are moderately hydraulic; and those from stones of the lias formation (known as LIAS LIMES) are eminently hydraulic. There are "blue" and "white" lias limes, but

the terms refer to the colour of the stone from which they are burnt, and not to that of the resulting lime.

It is to be noted, however, that the fact that a manufacturer calls his lime a Lias Lime need, according to a recent legal decision, be no guarantee that it is produced from stone from the lias formation, this fact having to be specifically mentioned if such lime is desired.

Analyses of Typical Stone and Lias Limes.

Castle Bytham Lime.

(Stone lime, moderately hydraulic.)

SiO_2	14·00
$Fe_2O_3 + Al_2O_3$ ...	4·25
CaO	77·00
MgO	1·25
CO_2	0·90
Water and loss ...	2·60
	100·00

Harbury Lime (Warwickshire).

(Lias lime, eminently hydraulic.)

SiO_2	17·53
Fe_2O_3	2·87
Al_2O_3	6·83
CaO	65·84
MgO	1·00
SO_3	1·36
$H_2O + CO_2$ ...	3·85
Insol. matter ...	0·50
	99·78

Analyses of Merstham Lime.

Grey Stone Lime (Yellow).

Lime	80·24
Magnesia	0·50
Oxide of iron and alumina	4·60
Potash and soda ...	1·25
Insoluble[2] silica ...	11·40
Combined[3] water ...	2·01
	100·00

Chalk Lime (White).

Lime	91·22
Magnesia	1·50
Oxide of iron and alumina	0·80
Potash and soda ...	0·85
Insoluble[2] silica ...	1·60
Combined[3] water ...	4·03
	100·00

When ground, blue lias lime averages eleven 3-bushel sacks to the ton (a striked bushel filled from a hopper averaging about 68 lbs.). It will be found that two sacks of ground blue lias lime with the addition of sand (in proportion 1 to $2\frac{1}{2}$) will in the dry state measure roughly one cubic yard, and that one sack of lime with the addition of sand and ballast (in proportion 1 to 6) will, before water is added, measure about one cubic yard.

Ground lime in bags should be kept in a dry place, and if not used within a short time (especially in damp or warm weather) the lime should be shot (under cover) to prevent its bursting the sacks.

Briquettes of the Harbury lime and sand have been tested by the owners, Messrs. Greaves, Bull, and Lakin, Limited, under the conditions usual when testing Portland cement, and have given, so far as they have gone, the following results with tolerable uniformity:

	Broke under
6 parts of sand to 1 of lime, after 2 weeks immersion in water.	30 lbs. per sq. inch.
6 parts of sand to 1 of lime, after 52 weeks immersion in water.	120 lbs. per sq. inch.
3 parts of sand to 1 of lime, after 52 weeks immersion in water.	195 lbs. per sq. inch.

Lime which commences to set on the addition of water, without any appreciable slaking action first taking place, is known as a cement. Stones which burn naturally to cements are to be found to a large extent in some parts of the country, notably as rounded lumps of chalk which have been embedded for long periods in beds of clay, from which the once well-known Roman cement was made; but the product was so far inferior to the little less costly Portland cement, the process of manufacture of which will be explained in a later chapter, that it is scarcely, if ever, made now.

The moderately and eminently hydraulic limes may be used in the ground-powder form hot, without slaking, and in any case should be used within a few days of mixing and before material setting commences; but lump lime and the purer limes must always be slaked.

Messrs. Greaves, Bull, and Lakin issue the following directions with regard to slaking their lias lime:—

Care should be taken in slaking lump lime, and it is recommended that it be first broken into small pieces, then evenly sprinkled with water (preferably through the rose of a watering-can) and covered quickly with sand. It should be left in this state for at least twenty-four hours before being used.

Any unslaked pieces may be put into the middle of the next heap to be slaked.

No water should on any account be added after slaking has begun.

It will be found that the proper quantity of water to be used in slaking is about a gallon and a half to every bushel of lump lime.

Only so much lime should be slaked at one time as can be worked off, say, within a week or ten days.

SELENITIC LIME is made by this same firm by calcining the lias rock from picked beds, which burn to a quick-setting natural cement, and grinding in raw gypsum with the calcined product, thus slowing down the setting power to within reasonable limits without any liability to slake. The resulting product will carry a large proportion of sand without serious loss of strength.

MINOR LIME PRODUCTS.

WHITEWASH is a mixture of white quicklime and water. Any lime can be used so far as its efficacy is concerned, but where, as in the case of lias, the lime is slightly tinted, the whiter lumps are picked out for conversion into white-wash. The lime should be mixed up while "hot" with

plenty of water, and applied at once with a large brush to the surface to be coated. The process, known as *lime-whiting*, is exceedingly inexpensive, and is almost universally employed where, for sanitary reasons, frequent re-application is desirable.

Whitewash is by no means durable, as it rubs off easily, is washed away by rain, and does not adhere well to smooth surfaces. Constant renewal is therefore necessary, and it should not be used at all in exposed situations in its pure state.

A moderately permanent whitewash for external use can, however, be made by thoroughly slaking lime in boiling water and adding sulphate of zinc and common salt, the proportions being 1 bushel of lime, 4 lbs. zinc sulphate, and 2 lbs. salt, with enough water first to slake the lime and then to dissolve it.

WHITING is a name for powdered chalk which has not been calcined. To prepare it for use, 6 lbs. of this powder is covered with water for six hours, when it is mixed with 1 lb. of double size and left in a cool place to become like jelly, when it is ready to be diluted with water and used. It is commonly applied to plaster ceilings where better work than that obtained by lime-whiting is desired, the process being known as "whitening." It will not stand the weather.

Thus to *limewhite* a ceiling is to coat it with whitewash, only one coat being possible; while to *whiten* a ceiling is to coat it with whiting and size, several coats being possible and two being usual.

PUTTY is made by mixing dried and finely-ground whiting, free from grit, with raw linseed oil. After being mixed it should be left for twelve hours, or it is made and sold in bulk, a small portion being taken and further kneaded up by hand as required.

Where unusual adhesiveness is required, as in glazed fanlights with small lap, a little white-lead may be added to the putty with advantage; while a hard putty can be

made by using turpentine instead of some of the oil; and an even harder putty by introducing white-lead, red-lead, and sand. These hard putties should, however, be painted soon after they are applied, as they are liable to crack.

Soft putty is made by mixing 1 lb. of white-lead and ½ gill of the best salad oil with every 10 lbs. of whiting and the necessary linseed oil, the white-lead strengthening its adhesive properties, while the salad oil keeps it soft enough to prevent hardening, cracking, and consequent falling off.

Much the same result is achieved by mixing tallow with putty, rendering it "thermo-plastic," as it is called—that is, sufficiently pliable not to be loosened by the expansion and contraction of glass in large sheets under different degrees of temperature.

To soften old putty for the purpose of removing it, it is only necessary to apply heat in the form of a piece of heated metal, using it as a laundress uses an iron.

Chapter XII.

PORTLAND CEMENT: ITS PROPERTIES, CONSTITUENTS, AND TESTS.

PORTLAND cement, by far the most valuable of the lime products, is formed by drying, burning, and subsequently grinding to powder an artificial mixture of clay and chalk, or of shale and limestone. The resulting material, on the addition of water, has the property of setting, either in air or water, to rock-like hardness while at the same time binding or cementing together any materials with which it is in contact. It is also, when set, almost impervious to water.

By means of recent microscopic investigations, four distinct mineral constituents, known as Alit, Belit, Celit, and Felit, exist in Portland cement clinker, and of these alit and celit are the most important; the clinker being a highly complicated solid solution of these substances formed by "sintering"—that is, by diffusion at a temperature below that of the melting point. Perfect diffusion, by exposure to the proper heat for the right period of time, is essential for the production of good clinker; and this explains why clinker turns to dust which has not attained as high a temperature as that in the hottest part of the kiln.

Thus a proper chemical composition is not of itself any guarantee that the cement will be a satisfactory one, as the materials of which it is composed may not necessarily have attained thorough diffusion, and consequently may not be in equilibrium.

According to Mr. Clifford Richardson, of New York,

the true Portland cement ratio, neglecting extraneous substances, may be regarded as extending from :—

	SiO_2	Al_2O_3	CaO
Pure tri-calcic silicate	26·4	0·0	73·6
to $7(SiO_2\ 3CaO)\ (3Al_2O_3,\ 2CaO)$ ...	18·9	13·6	67·5

Beyond the latter degree of concentration he considers that the solutions or clinkers have not the structure of Portland cement, and cannot be regarded as such, although they are hydraulic.

Setting begins to take place almost directly water is added. It is therefore essential that it should be used at once, only so much being mixed as is required immediately, for if cement be beaten up which has definitely begun to harden it loses a great part of its adhesiveness and cohesiveness, becoming little better than so much sand, and fit for nothing else than to be thrown away; for though these properties can be restored by reburning and regrinding, this is not economically practicable.

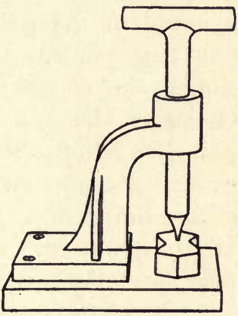


Fig. 35. Vicat Needle.

The period occupied in setting varies considerably; for though it is rarely less than one hour or more than seven, both quicker and slower setting cements can be made if required by varying the constituents and the manufacture slightly. As a rule this is not a matter of very great importance, except that the slower setting cements allow of greater latitude in mixing, and give time for any particles of free lime to be acted upon and slaked; but occasionally, especially in tidal work, quick setting is imperative, and in such a case the manufacturer should be informed and should not be tied to too rigid an analysis so long as other requisite qualities are not impaired. The correct test for setting is that of no perceptible impression

being made by the point of a Vicat needle (see Fig. 35) having an $\frac{1}{8}$ in. point of ·015 square inch area and weighing 10·5 ozs., this being allowed to rest lightly on the briquette, or on a mass of cement $1\frac{1}{2}$ ins. thick placed in a glass dish having a diameter of 3 ins.; setting being considered to have commenced when the needle no longer sinks to the bottom of the dish. Many users, however, employ the rough-and-ready test of thumb-nail pressure.

Fresh cement, when first emptied from the casks or sacks in which it is sold, is generally "hot"—that is, it slightly stings the bare hand or arm if plunged into it, or if a paste be made with water and the bulb of a thermometer inserted in the paste, a considerable rise of temperature will take place, up to as much as 12° Fahr. in an hour. Some rise is essential, for it shows that the necessary chemical changes which take place during setting are going on; but a rise of more than 6° indicates that the cement contains unburnt, or at any rate unslaked, particles of free lime whose presence may have very serious results. Hot cements will expand from this cause, sometimes at once, sometimes not till long after the work in which they have been used has been finished, and so are very particularly to be avoided, except occasionally in underpinning work, when a little expansion may be useful. A concrete upper floor has been known to expand and burst the building it was inserted in a year after completion.

According to tests made by the Cement Users' Testing Association, a first-class fresh cement, mixed with 20 per cent. water, expanded, on mixing, $\frac{1}{8}$ in. per 100 ins. in one day and $\frac{1}{4}$ in. per 100 ins. in seven days, or at the rate of 1 in. in 33 ft. 4 ins.

Hot cement should therefore always be cooled by being spread on a wooden floor under cover to a depth of not more than 12 ins., with a good current of air passing over it, and turned over occasionally, until the rise of temperature of a sample made into a paste with 20 per cent. of its weight of water is not more than 6° Fahr. in an hour

after mixing. Hotter cement than this is unfit either for use or testing.

On the other hand, cold cement, which shows little or no rise of temperature, is inert and valueless, having lost its power of setting. Cement may become cold by too long exposure to air in too thin layers.

Expansion may also be due to over-liming, and in this connection the following analyses of satisfactory material and product may be valuable :—

FINISHED WARWICKSHIRE CEMENT.

Made by Messrs. Greaves, Bull and Lakin, Limited :—

H_2O and CO_2	0·29
Insol. matter	0·34
SiO_2	20·44
Al_2O_3	9·30
Fe_2O_3	3·70
CaO	62·16
MgO	1·74
SO_3	1·97
	99·94

WARWICKSHIRE RAW MATERIAL.

Authority, D. B. Butler, A.M.Inst.C.E., on "Portland Cement" :—

LIAS STONE.		LIAS SHALE.	
Silica	8·73	Organic matter	3·72
Alumina and oxide of iron	8·78	Silica	30·05
Lime	43·95	Alumina	10·70
Magnesia	1·87	Oxide of iron	3·30
Sulphuric acid	·74	Lime	26·80
Alkalies	trace.	Magnesia	3·68
Carbonic acid	36·20	Sulphuric acid	1·43
		Carbonic acid	20·08
		Potash	0·19
		Soda	0·13
	100·27		100·08

Medway Raw Material.

Mud (or *Clay*) from Gillingham.
Authority, C. Spackman, F.C.S. :—

Silica...	38·413	As sand in an extremely fine state of division.
Alumina with trace of iron	1·856	
Silica...	25·249	As hydrated silicates.
Alumina	14·244	
Ferric oxide ...	6·744	
Lime...	0·810	
Magnesia	1·727	
Potash	2·957	
Soda	0·773	
Water	3·384	
Iron pyrites	0·214	

Chalk.—This substance commonly contains 92—94 per cent. of pure carbonate of lime, with very small amounts of silica and alumina.

Finished Medway Cement.

Made by Messrs, J. C. Johnson & Co. Authority, Cement Users' Testing Association :—

Moisture	0·37
Alumina	7·35
Insoluble matter	2·37
Combined water and organic matter ...	0·95
Ferric oxide	3·47
Sulphuric acid	1·25
Magnesia	0·99
Carbonic dioxide	0·93
Lime	60·39
Soluble silica	21·41
Undetermined	0·52
	100·00

According to the Cement Users' Testing Association, a first-class cement should not contain more than 1·25 per cent. of magnesia, 1·75 per cent. of sulphuric acid, 1 per cent. of carbon dioxide, or 1·5 per cent. of insoluble residue, nor more than 61 nor less than 56 per cent. of lime. These, however, are severe demands, with which neither of the above analyses comply, though both cements are recognised as being good and reliable.

Another great enemy to the soundness of a cement, though it quickens its setting properties, is the inclusion of any material proportion of underburnt clinker. This, which is bright yellow in colour, should be picked out during manufacture, and its presence is usually easily detected by the yellow colour of the cement powder, which ought to be a dull grey.

An underburnt cement, too, has a low specific gravity. When properly cooled to a rise of temperature of 6° Fahr. in an hour after mixing, good cement should have a specific gravity of at least 3·08 ; but newly burnt cement is heavier, and should have a specific gravity of at least 3·125. The test is rather a difficult one to apply, and should be done in oil, in a Schuman's or Keate's bottle ; but it is at least reliable, which is more than can be said for any test of the mere weight of a measured sample.

The great test for absolute soundness is that of boiling. A circular pat of neat cement, which it is essential shall be properly cooled, about ½ in. thick and 3 ins. in diameter, is made up on glass with 20 per cent. of its weight of water. This is kept in moist air for twenty-four hours, and then immersed in cold water, which is raised slowly to boiling point and kept at that temperature for three hours. Under this test a bad cement will turn into soup, while an unsound one will crack from expansion or curl up at its edges from contraction. Only a thoroughly good cement will retain its form under this severe test, which requires great care, and should only be applied by an expert possessing the proper apparatus. Even

the best cement, too, will not stand it if tested while "hot."

The effect of boiling is to accelerate the changes which take place in a cement in use, expansion taking place in a few hours instead of several months.

A modification of this test, which may be safely relied upon in most cases and used by the comparatively unskilled manipulator, can be made by means of an appliance like an incubator, in which the temperature is maintained within a degree or two by a cleverly arranged valve (not shown in the illustration) which regulates the supply to the gas burner.

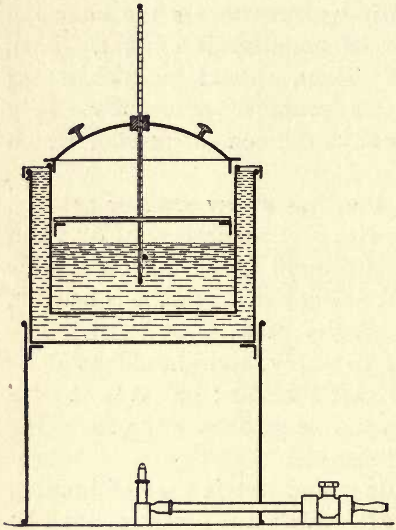


Fig. 36.

It also is based on the principle that moist heat accelerates the setting of cement, and that if judiciously applied, the age of several days may be artificially given to a cement in a few hours. A sound cement acquires great hardness in a short time when treated in this apparatus, but an unsound one, or one that would under ordinary conditions "blow" when used in work, is caused to develop this characteristic in a few hours; and hence, by use of this apparatus, a definite opinion may be formed as to whether a cement is a safe one to use or not; independently, of course, of its tensile strength, which may or may not be equal to that required.

The apparatus (see Fig. 36) consists of a covered vessel

in which water is maintained at an even temperature of from 110° to 115°, or even by some authorities up to 120° Fahr.; the space above the water is therefore filled with the vapour arising therefrom, and is at a temperature of about 100°. Immediately the pat is gauged it should be placed on the rack in the upper part of the vessel, and in five or six hours it may be placed in the warm water and left therein for nineteen or twenty hours. If, at the end of that period, the pat is still fast to the glass, or shows no signs of blowing, the cement may be considered perfectly sound; should, however, any signs of blowing appear, the cement should be laid out in a thin layer for a day or two, and a second pat made and treated in the same manner, as the blowing tendency may only be due to the extreme newness of the cement.

A tendency to "blow," or expand after setting is often caused by the inclusion of coarse particles in the cement, which contain free lime within them. Such particles have little strength or cementing value, and their presence is therefore highly undesirable, especially as it is exceedingly difficult, by the ordinary process of air-slaking which cools the finer particles of free lime and renders them innocuous, to similarly get at the lime concealed in a metamorphic condition in coarse lumps of hard cement.

Fine grinding is therefore essential for safety, and it has the added advantage of putting the cement into a condition in which its quality of adhesion can be most highly developed, giving it great "covering" power, and enabling it to penetrate the tiniest crevices; and this even though extremely fine grinding reduces its cohesion.

All good cement is now reduced to an impalpable powder. The actual results, taken at random from the records of Messrs. J. and C. Johnson, with two different mills, were as follows, the percentage residues by weight being ascertained after sifting through meshes of 2,500, 5,625, 10,000, and 14,400 holes per square inch respectively:

TABLE OF RESIDUES.

MESH. No. of Holes per Sq. In.	RESIDUES.—Percentage by Weight. First Sample.	Second Sample.	Standard Diameter of Wire.
			Ins.
2,500	0·02	0·01	·0068
5,625	2·00	1·10	·0044
10,000	9·40	6·30	·0032
14,400	14·00	10·50	·0024

It is extremely important that testing sieves should be uniform, with the mesh of standard wire whose diameter is equal to half the breadth of the hole. The diameter of wire for all the ordinary sieves is given in the last column of the above Table; but much finer sieves, with correspondingly finer wire, are occasionally made and used, down to one with 36,000 holes per square inch.

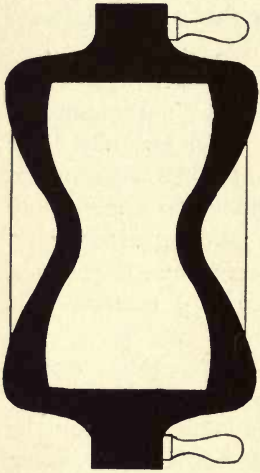


Fig. 37. Briquette Mould.

According to the Cement Users' Testing Association, a first-rate cement should leave a residue of not more than 5 per cent. on a sieve of 5,625 meshes, nor more than 12 per cent. on a sieve of 14,400 meshes per square inch.

The same Association suggests, as a test of adhesion, that a pat of cement 3 ins. in diameter and ½ in. thick should, after the expiration of seven days, adhere firmly to the natural cleft surface of a Welsh slate, the slate to be soaked in water prior to the application of the cement, and the whole to be kept slightly moist during the interval.

A very high resistance to tension, or power of cohesion, is not necessarily an advantage, as it may be due to the

cement being "hot" or to its containing an excess of lime; but it is a highly valuable quality in a finely ground and properly cooled cement which will stand successfully the boiling or the incubator test. According to the Cement Users' Testing Association, neat cement should bear a tensile stress of 400 lbs. per square inch after seven days' immersion in water, 500 lbs. after fourteen days, and 600 lbs. after twenty-eight days; while a mixture of 1 part of cement to 3 of "standard" (Leighton Buzzard) sand should bear a stress of 100 lbs. after seven days, 150 lbs. after fourteen days, and 200 lbs. after

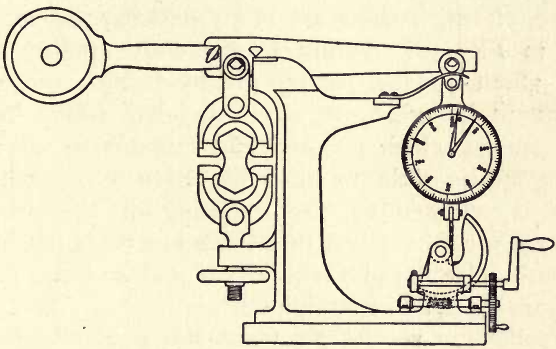


Fig. 38. Faija's Testing Machine.

twenty-eight days; the increase in all cases to be uniform.

Most manufacturers will undertake to supply much stronger cement than this, but in the majority of building works excessive tensile strength is by no means so important as absence of expansion, cracking and shrinkage.

For the purpose of testing cohesion, the neat and properly cooled cement is mixed with 20 per cent. of its weight of water, or the cement and sand with 10 per cent. of water, and pressed into iron moulds, of which one of the most usual forms is given in Fig. 37, having a sectional area of one square inch at the narrowest part, where fracture will

occur. Thumb pressure only should be used, as any artificial pressure or ramming will result in a much higher resistance; and as the thumb pressure of different individuals varies, it is best that any series of tests should be conducted if possible by the same person and under similar conditions.

The briquette thus made should be kept in a moist atmosphere at a temperature of at least 50° Fahr. for twenty-four hours, and then should be removed from the mould and placed in water at not less than 55° nor more than 60° until the period at which the test is to be applied. The briquette is then inserted in the clips of a testing machine, of which there are many patterns, Faija's being shown in Fig. 38. Strain is gradually applied, at the rate of about 400 lbs. per minute, by turning the handle, the amount being shown upon the dial, which has two hands, one of which is loose and remains to record the breaking strain, while the other flies back to zero when the tension is released by the snapping of the briquette. Great care must be taken that the briquette is put in truly and evenly, else the pull will be unequal and the fracture be diagonal instead of straight.

The following results bear out the generally received opinion that cement should be used as soon as possible after being mixed, the delay of only one hour producing very serious deterioration. The experiments were made upon briquettes composed of 2 parts of sand to 1 of cement, mixed with 10 per cent. of water:—

	Ultimate tensile stress after two months. Lbs. per sq. in.
Mixed one hour before putting into moulds	83
Put into moulds at once	220

On the other hand, the effect of colouring matter is advantageous, so far as experiments have yet gone to prove it.

The effect of colouring matters.—Briquettes made with standard sand and cement 2 to 1 :—

	Ultimate tensile stress after two months. Lbs. per sq. in.
Coloured with 5 per cent. ultra-marine ...	304·5
Coloured with 7·5 per cent. oxide of iron ...	325
Coloured with 4 per cent. lamp black ...	286·5
Uncoloured cement mortar	276

It is also worth noticing that a highly aluminous cement which, after plastering, will set in an hour, has often been found to set in three minutes when stored in closed freight cars for some time in a hot summer's sun.

Chapter XIII.

PORTLAND CEMENT: ITS MANUFACTURE.

THERE are at present three principal methods employed for the manufacture of Portland Cement, these being exemplified by the works of Messrs. J. C. Johnson & Co., at Greenhithe; those of Messrs. Greaves, Bull and Lakin, Limited, at Harbury, in Warwickshire; and those of the Associated Portland Cement Manufacturers (1900), Limited, at Swanscombe, in Kent. Though probably no two firms work on exactly the same systems, these may be considered as typical of what, for want of better names, may be termed the "Ordinary," and the "Semi-Dry," and the "Rotary" processes respectively.

The clay is brought in barges to Messrs. J. C. Johnson & Co.'s works, and the chalk is quarried on the spot. These raw materials, which naturally vary somewhat, are constantly analysed, and the proportions in which they are mixed are altered from day to day accordingly. The chalk and the clay are filled into barrows of different sizes, and each barrowful is weighed and then tipped into a circular pit with ample water in it, about three of chalk to one of clay. The pit has a vertical axle carrying arms like windmill sails, only with blade attachments in place of sails, and these being given a rotary motion, beat up the contents of the pit into a creamy liquid, which is driven out through a grating. The "slurry," as this mixture is called, is next passed between horizontal grindstones, like those used for grinding corn, which reduce it to such a degree of fineness that all will pass through a sieve of 2,500 holes per square inch, and only 5 per cent. be retained on a 32,000-hole mesh.

At one time the slurry was run into large open-air "backs," or shallow reservoirs, to settle, but this has now been entirely abandoned in favour of artificial drying by the aid of the spare heat from the kilns (see Fig. 39).

The hot air passes over the slurry, of which the drying

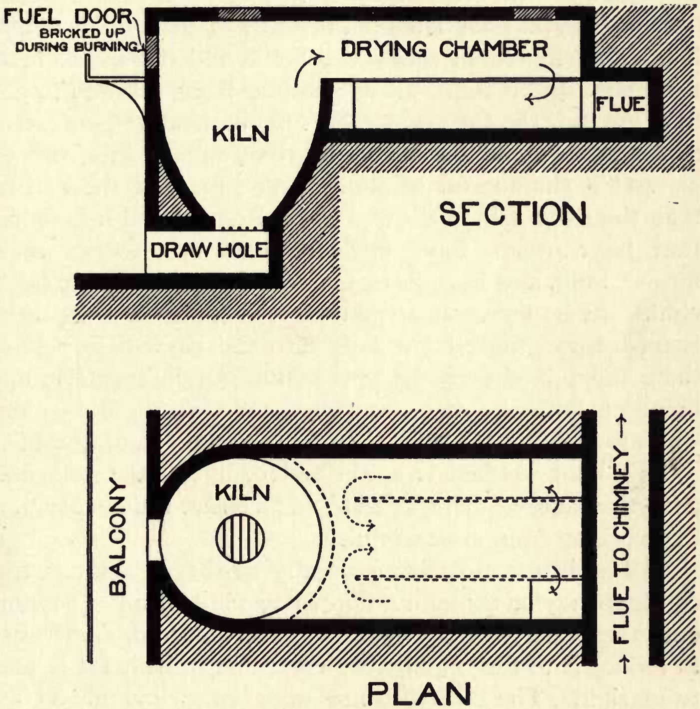


Fig. 39. Johnson's Portland Cement Kiln.

chamber contains just enough with which to charge the kiln, then down through holes in its iron floor, circulating between dwarf walls as shown by the arrows on plan, and thence to a long continuous flue the entry to which is controlled by a damper. This flue serves for a long range of kilns, and leads to a large central chimney.

The dried slurry, now known as "slip," is filled into the

kiln, mixed with small coal to act as fuel, the kiln being piled right up to its arched roof. As soon as it is full, and the drying chamber empty, a rough wall of slip is built round the kiln edge, and a fresh charge of slurry is pumped on to the floor of the chamber. All openings are then bricked up with fire-bricks set in slurry, except a small hole in the fuel door left for purposes of inspection which is temporarily closed with a dry brick, and the kiln is fired from beneath, as much air as possible being allowed to get to it through the fire-bars. An intense heat is generated, and it takes about a week to burn through a kiln, and to convert a chamberful of slurry into slip. At the end of that time the kiln is allowed to cool down, and it is found that its contents have been reduced to one-half their former bulk, and have been converted into a hard metallic clinker of honeycomb structure. The fire-bars are now removed and the clinker falls into the draw-hole. It is there filled into barrows, any yellow (underburnt) lumps being put on one side to be passed through the kiln again, while the good clinker is taken to powerful grinding mills.

This final product is again tested, by all the principal analytical and mechanical tests, and a check thus kept upon the working from start to finish.

Ball and tube mills are generally used for grinding, the clinker being fed through a hopper to the ball mills, passing out as a powder, which goes through the tube mills afterwards to reduce it to the impalpable condition in which it is sent to market. The Ball-mills are large hollow cylinders containing a number of steel balls which grind against one another as the horizontally placed cylinders revolve on their axes; while the Tube-mills—long steel tubes set to a slight incline—are half full of flint pebbles, which in a similar manner rub against one another, grinding the clinker and powder as the tubes revolve.

The "Semi-dry" Process, as exemplified at the works of Messrs. Greaves, Bull and Lakin, differs only from the above so far as is necessitated by the raw materials being

hard instead of soft; blue lias limestone taking the place of chalk, and a hard shale that of the clay. Crushing is consequently the first operation, and then grinding under an edge runner so as to pass through a $\frac{1}{4}$ in. mesh formed in the pan of the mill. Mixture then takes place with only a little water, so as to pass the ingredients between horizontal grindstones, producing a dark-coloured slurry of about the consistency of porridge. This is pumped on to the drying floors of Johnson kilns, and the subsequent treatment is exactly similar to that already described, except that the heated air from the kiln, after passing over the contents of

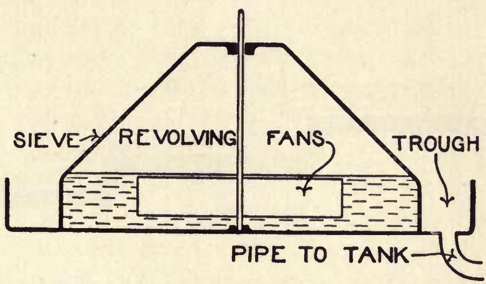


Fig. 40. Mechanical Slurry Sieve.

the drying chamber, is carried under iron plates on which is spread a thin (3 ins.) layer of slurry. When a kilnful of slip has been heated through and collapsed, slip from this supplementary drying chamber is introduced to fill it up again, without any more fuel; and as this burns in the heated kiln just as thoroughly as does that which is first inserted, a distinct economy is effected.

At the Swanscombe works of the Associated Portland Cement Manufacturers (1900), Limited, the slurry, after being mixed in small pug-mills or "wash-mills," and ground between French Burr-stones, is pumped into a mechanical sieve (see Fig. 40), consisting of a circular basin in which beaters or fans revolve at considerable speed, throwing the liquid forcibly against an inclined sieve of 1,225 holes per

square inch. Any materially coarse particles are thus retained, while what passes through would leave a residue of but 5 per cent. on a 32,000 mesh. This sifted product, little denser than milk, is collected in an external annular trough and passes in a continuous stream through a large pipe to one of several great mixing tanks, each capable of holding 1,200 tons of slurry. These also are circular, with massive beaters slowly revolving in them to thoroughly incorporate the contents and prevent settlement. The effect of this complete mixing of large quantities of slurry is the production of a cement of almost uniform analysis, the variations which inevitably occur in mixture in small

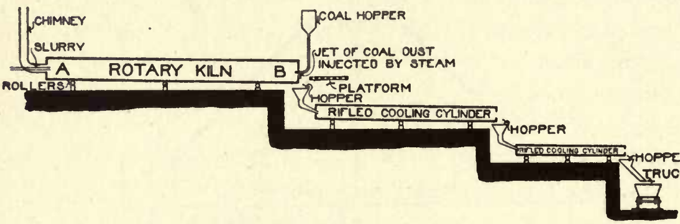


Fig. 41. Rotary Portland Cement Kiln and Cooling Cylinders.

amounts being compensated when mixture takes place in bulk.

The subsequent processes by means of which the slurry is converted into clinker ready for grinding are shown in rough diagrammatic form in Fig. 41. The slurry is pumped directly into the end of A, a large ROTARY KILN, in the form of a steel cylinder, 70 ft. long and 6½ ft. in diameter, set to a slight fall from A to B, lined with fire-bricks internally, and revolving on rollers at any desired speed. At the open lower end B, a jet of coal dust, ground in Griffin mills to a fine powder, is injected by the aid of steam and compressed air, falling in a light spray and being converted into flame at once, generating a temperature of some 3,000° Fahr., the products of combustion passing up the kiln from B to A while the slurry passes through it

from A to B, entering at A as liquid slurry and passing out at B as red-hot clinker of about pea-grit size, after about an hour and a half. In this short space of time the moisture has been evaporated from the slurry, passing up the chimney as steam, and the "slip" thus produced has been rendered bone-dry about the middle of the kiln and burnt to clinker at the lower end. The rotary motion, throwing the slurry into drops and the slip into small lumps, greatly facilitates the burning, which can be rapid as well as thorough, the small pieces becoming quickly and completely calcined.

The burnt clinker, which is entirely free from dust, falls over the edge of the kiln at the lower end B, as it rotates, into a hopper, and passes thence into another long revolving cylinder through which a current of cold air passes—and thence to another similar cylinder in the same way. These cooling cylinders are rifled with deep grooves throughout their length, so that as they revolve the lumps of clinker are caught and dropped, to assist in cooling them; while the air which enters at the lower end of the cooling cylinders, having been gradually warmed as it passes over the hot clinker, is then introduced into the kiln—though the way in which this is done is not shown on the accompanying diagram.

The Cement Clinker is subsequently ground in the usual way by means of Ball and Tube Mills.

Chapter XIV.

MORTAR—FIRE CEMENT.

MORTAR is the substance used for filling up the interstices between the blocks of solid material of which a wall is built, forming at the same time a soft and level bed for the blocks to lie upon, so distributing the load evenly over the surface of the lower blocks, and to a greater or less extent cementing the blocks together so as to form one homogeneous whole. It is generally composed of lime and sand, or of substitutes for these materials, in varying proportions, roughly gauged by bulk, so that the matrix (lime or cement) may just fill up the natural interstices between the particles of the aggregate (sand).

Pure and poor limes should not be used ; but the following list gives the proportions of different materials in general use for different classes of work :—

Ordinary brick or stone walling.	1 part of stone lime to 3 of sand.
Good walling	1 part of selenitic lime to 4 of sand.
Very good walling and piers, to carry considerable loads slowly applied, or light machinery.	1 part of lias lime to $2\frac{1}{2}$ of sand.
Quick setting walling, and piers and walls to carry heavy loads.	1 part of Portland cement to 4 of sand.
Exceedingly strong work, and watertight work such as pointing.	Neat Portland cement.

Lime mortar should be used where shattering or swaying motion has to be resisted, as in tall chimney stacks and church spires, a certain amount of "play" being advisable under such circumstances; but for rigid resistance there is nothing to equal cement. Thin walls, such as half-brick partitions, should also be built in cement mortar, although lias lime mortar is admissible if they are not more than about 9 ft. high and are supported by cross-walls pretty frequently.

Careful mixing of the ingredients of mortar is quite as important as the use of proper proportions. On small works this is done by hand, and the following instructions issued by Messrs. Greaves, Bull and Lakin may be taken as being equally applicable under such circumstances to mortar composed of any moderately or eminently hydraulic lime:—

GROUND LIME should be used in the proportion of 1 bushel of lime to 2½ or 3 bushels of clean, sharp sand, free from dirt or loam. This should be first thoroughly mixed in its dry state, which may be done by turning them over together several times with a shovel, and afterwards, to ensure a more perfect mixture, passing the whole through a riddle. (It should be borne in mind that a complete incorporation of the ingredients is most essential.) After this has been done the mixture should be left in a heap for a day or two. Mortar may then be made from the heap as required by the addition of water, and a further mixing in the wet state.

When LUMP LIME is used instead of Ground, special attention should be given to the instructions for slaking (see p. 111), and the slaked lime and sand should be passed together through a riddle.

The amount of water required for mixing mortar will depend on the quantities and nature of the materials used, but in the above mixture (say 1 to 3 of sand) it would be from 1½ to 2 gallons per bushel of lime and sand. This is in addition to that used in slaking the lime.

Much more perfect incorporation is, however, secured by the use of a MORTAR MILL, and as it is more economical to employ one than to mix by hand on even a moderate scale, it is generally used, especially where power is available. There are two types—those which are self-delivering, these being most suitable for hard, rough grinding ; and those which have revolving pans passing beneath edge runners. Of these the latter is in more general use, one (the "Century," made by the Glendon Engine Works Co.) being illustrated in Fig. 42. There is a false bottom-plate of hard iron to

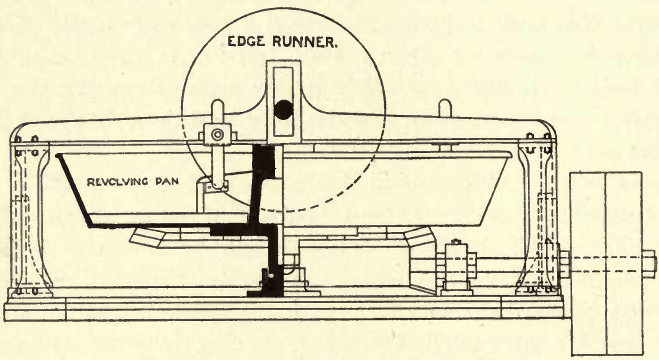


Fig. 42. The "Century" Mortar Mill.

the pan, which can be renewed when it wears away from contact with the heavy metal rollers.

Where there is a Mortar Mill, Messrs. Greaves, Bull and Lakin's instructions are as follows :—

Either Lump or Ground Lime can be used, and the mortar may be made in proportion of 1 part lime to 3 or 4 parts sand. The sand must be thoroughly clean and sharp, and where this is not readily obtainable, excellent results may be had by substituting (either wholly or in part, according to the selection made) good old broken bricks (clean and well burnt), well burnt ballast, stone chippings, furnace cinders or slag.

It is most essential in all cases that the materials used

should be perfectly clean and free from loam, clay, or other impurities.

The mortar should be left in the mill until thoroughly reduced and incorporated, but excessive grinding is detrimental.

When Lump Lime is used, it should, for the sake of economy of time and power, be wholly or partially slaked before being put into the mill ; and if this, either from want of space or otherwise, is not found convenient, Ground Lime should be used in preference, as the small extra cost is in most cases more than compensated for by the greater convenience in handling, and the saving of labour and room required in slaking.

If unslaked lime be passed direct into the Mortar Mill, more water and mixing will be required, and the mortar should stand for a few hours to allow the lime to slake.

Mortar made with SELENITIC LIME has to be treated in an entirely different manner. If prepared in a Mortar Mill, pour into the pan of the edge runner two full-sized pails of water, then gradually add one bushel of Selenitic Lime, and grind to the consistency of a creamy paste, then throw into the pan 4 or 5 bushels of clean, sharp sand, burnt-clay ballast, or broken bricks, which must be well ground until thoroughly incorporated. If necessary, water can be added to this in grinding, which is preferable to adding an excess of water to the prepared lime before adding the sand.

N.B.—The water and the Selenitic Lime *must be mixed together first*, and, if Self-discharging Mortar Mills be used, the lime and water are preferably mixed in a tub, as explained hereunder, adding the paste to the sand proportionately as required in the Mortar Mill.

Where there is no Mortar Mill, an ordinary tub or trough (containing about 40 or 50 gallons), with outlet or sluice, may be substituted. In this case, pour into the tub six full-sized pails of water, and gradually add a 3-bushel sack of Selenitic Lime, which must be kept well

stirred till thoroughly mixed with the water to the consistency of a creamy paste. Form a ring with half a yard of clean sharp sand, into which pour the mixture from the tub. This should be turned over three or four times, and well mixed with the larry or mortar hook, adding water as necessary. One 3-bushel sack of selenitic lime requires about 18 gallons of water. There are 12 sacks to the ton.

CEMENT MORTAR needs still different treatment. It should not be mixed in a Mortar Mill because of the great risk run of grinding being prolonged after setting has commenced. The ingredients should first be mixed dry in a small heap, being turned over at least twice. Just sufficient water (about 15 per cent.) should then be added through the rose of a watering can, the mixture turned over once again and used immediately—at any rate, within half an hour of mixing, and much sooner than this if the cement be quick setting. Neat cement is generally mixed with just enough water on his palette by the bricklayer himself only a few minutes before it is needed.

The bulk of mortar is about 25 per cent. less than that of the ingredients of which it is composed when separate and in their dry state. This is due to the interstices between the grains of sand being filled with the lime or cement and water, which are almost, and sometimes entirely, absorbed in this way.

Once mixed, all mortar should be placed in a tub or on a wooden platform to keep it clean until required for use. Only so much should be mixed at one time as can be used before it commences to set, and any which has begun to stiffen should be rejected. Unfortunately it is easy to throw into a mortar mill any which has been exposed through a night and has thus begun to set, and to mix it up with a little fresh lime and use it, and a good deal of indifferent work is traceable to this cause.

Moisture assists the setting action of all hydraulic limes and cements, while if deprived of its moisture before setting

has taken place a mortar will revert to its original constituents and become mere inert sand. Consequently in hot weather all brick or stone used in building should be well soaked, else the moisture will be rapidly drawn from the mortar into the thirsty bricks, and setting will not take place—this being more apparent in mortars made with slow setting limes than in those made with the quicker setting cements. In all cases work executed in damp earth or under still water becomes eventually harder than that done in air.

Frost also rapidly destroys unset or partially set mortar. In frosty weather work must either be stopped or executed in a cement mortar which will set more quickly than it will freeze.

Mortar should be used of as stiff a consistency as possible, all beds being even, all surfaces covered, and all joints flushed up—that is, in walling.

A liquid mortar, known as GROUT, is often poured over the surface of a brick floor and swept over it with a broom so as to penetrate every crevice, but it should not be employed in walling; for, though excessively rapid work can be done by laying a thick bed of soft mortar and running the bricks along it into place, the practice is far from commendable.

FIRE CEMENT.—Where mortar has to be employed in a position where considerable heat has to be withstood, either raw fire-clay should be used, or a fire-resisting cement known as "PURIMACHOS" may be employed. Its composition is a secret, but its qualities are unquestionable. The following particulars are taken from the manufacturer's circular:—

Definitions.—The word cement means the moist paste; the word powder means the dry powder; the word wash means the moist paste or cement reduced with clean water to the consistency of whitewash.

Cement (Moist).—The white and dark cements are equally efficacious as fire-resisting materials. The white is generally

used for glazing and for other purposes where the colour of the work or surroundings have to be matched. The dark is generally used for general repairs, it being lighter in weight. The cement is sent out ready for use, and may be used for most purposes for which fire-clay is employed. It should, as a rule, be applied in the same manner—in the consistency of newly tempered mortar. If too stiff, add a little clean water; for resisting great heat, add powder (failing it, sifted fire-clay) well mixed together.—The cement is not intended to be brought in contact with lime, chemicals, fluxes, etc.

Powder (Dry).—The powder is not cement in a dry state, which can be converted into plastic cement by wetting it; it is an entirely different composition, and is not to be used by itself. It is prepared for combining with cement in cases of great heat; to impart to it greater body; or to cause it to set more quickly when cold. See also next paragraphs.

For moderate heats—*i.e.*, not exceeding 1200° Fahr.—(as in open fire-grates, or in pointing round kitchen ranges, etc.) the cement should be used by itself.

For very high temperatures (as in modern kitchen ranges, *i.e.*, in lining the fireholes), the best results will be obtained by the admixture of a sufficient quantity of powder (failing it, sifted fire-clay); and, as a rule, the greater the intensity of heat to be encountered, the greater should be the proportion of powder (say 1 to 3 parts or more of powder to 1 of cement): a little experience soon determines the exact proportion in each case.

Mixing.—The best method of perfectly and readily mixing together the cement and powder is this:—In a clean bucket, reduce the required quantity of cement to a batter or wash, to which add gradually the proper proportion of powder (or failing it, sifted fire-clay). With a trowel work up the whole thoroughly well to the consistency of newly tempered mortar. It is absolutely essential that the cement should be first reduced to a batter or wash as

described above ; and then after this batter has been made up, powder (or sifted fire-clay) may be added slowly and by degrees and thoroughly well mixed in and completely blended evenly throughout the whole mass. The mixing, if done in any other way, may produce failure and disappointment. Do not mix more than is required for immediate use.

Before applying Purimachos, remove all dirt, dust, grease, grit, carbon, rust, or loose pieces, so that the cement may adhere to a firm surface, and not to any loose substances.

Iron surfaces should be similarly cleaned ; and, where upright or sloping surfaces have to be covered with a layer of Purimachos, it is desirable to roughen the metal with an old file, bent to a suitable shape to act as a scraper. Then apply a wash with a clean brush, and let it dry. Upon this a layer may be applied to the required thickness, and thus get a better grip of the iron.

Joints in brickwork should be made very narrow with Purimachos. In jointing cracks, work it well in—do not merely plaster it outside. In cases of large fissures, etc., and where there is a difficulty in keeping it from falling out—as in the arches of furnaces, etc., support it in position until heat is applied, when the whole mass will set quickly with a slight expansion. Wooden supports may be used and allowed to burn away.—Purimachos may be applied to a cool or hot surface ; but it is desirable to apply it whilst cool. To ensure a perfect finish, plaster with Purimachos should be as thin as possible.

Chapter XV.

LIME PLASTER—PLASTER OF PARIS—SIRAPITE—KEENE'S, MARTIN'S, & PARIAN CEMENT—STUCCO—ROUGH CAST—NOTES FOR USERS.

ORDINARY plaster is, like mortar, composed of lime and sand, the principal difference between the two materials consisting in the lime for plaster being "pure" or non-hydraulic. No powerful cementitious quality is required, so long as it will adhere to a rough surface and can itself be brought, by the application of successive coats each finer than the last, to a smooth and level surface. On the other hand, it is generally required to be porous and absorptive of moisture contained in the air, which otherwise would condense upon the plastered surface and run down it in unsightly streaks.

The lime used must be thoroughly slaked, so that it shall not "blow" (or blister) after being used. A ring of sand is usually made, and the lime well slaked within this ring and left covered with water, the sand being presently mixed with it and the whole heap again left for some weeks to weather before use. There is rather more sand than lime and the mixture is known as COARSE STUFF.

When it has to be used on laths, which themselves are comparatively smooth while they have spaces between them into which the plaster is squeezed, ox hair should be mixed with the coarse stuff, in the proportion of about 1 lb. of hair to every 2 cubic feet of stuff. The hair should be long, free from grease, and well separated, preferably by immersion in water, and is best incorporated by hand with

a rake. If a mortar mill is used the hair should be added at the last minute and the grinding only continued long enough to ensure mixing, as if it is prolonged the hair is broken into short lengths and rendered valueless.

This, the first coat, is called "rendering" if on brickwork, and "plastering" or "pricking up" if on laths.

The second coat, known as "floating," may also be of coarse stuff, but there is in no case any necessity for it to contain hair.

The third, or finishing coat is much thinner than the first or second and, if it is to be papered, consists of FINE STUFF. This is pure lime which, after slaking with a little water, has been mixed with much, allowed to settle and the surplus water drawn off. The stodgy mass which remains, kept preferably in a large tub, is still left for the contained water to evaporate and the lime to thoroughly cool until it is wanted for use.

If the finishing coat is to be whitened or coloured with distemper of any kind, it should be made of PLASTERER'S PUTTY, which is almost identical with fine stuff, only more carefully made, run through a fine sieve, and kept from dirt.

For making good defects, and sometimes as a superior finishing coat, GAUGED STUFF is used, this being made by mixing plaster of Paris with plasterer's putty. Generally the proportion of plaster of Paris is about one-fifth of the whole, as a larger proportion may cause cracks to appear in the finished work; but gauged stuff is also used for running cornices and other ornamental work, when the proportion of plaster of Paris is increased to as much as 50 per cent. of the whole. The addition of this substance greatly hastens the setting (or hardening), so that only very little may be mixed at one time.

Selenitic lime can be used in place of pure lime for coarse stuff, it being made, where it is to be employed for rendering, exactly as is selenitic mortar (see p. 135). If for use as a first coat of plastering on laths, however, 9 bushels of sharp sand are added to a mixture, fresh made, of 3 bushels

of selenitic lime in 18 gallons of water, and then 3 hods of well-haired fine stuff mixed in. For the second coat the 12 bushels of sand would be used and the hair omitted from the putty.

If a hard face is required, prepared selenitic lime may be first passed through a 24 by 24 mesh sieve, to avoid the possibility of blistering, and used in the following proportion :—4 pails of water ; 2 bushels of prepared selenitic lime ; 2 hods of chalk lime putty ; 3 bushels of fine washed sand.

This should be treated as trowelled stucco, first well hand-floating the surface and then well trowelling.

A smooth and even harder face, if well hand-floated and then well trowelled, is produced by the following mixture : —Five pails of water ; 1 bushel prepared selenitic lime ; 1 bushel prepared selenitic clay ; 2 bushels fine washed sand ; 1 hod of chalk lime putty. It is suitable for the walls of hospital wards and public buildings, and, being non-absorbent, it is readily washed.

PLASTER OF PARIS is obtained by partially calcining or "boiling" GYPSUM (hydrous sulphate of lime), otherwise known as SELENITE, so that it parts with most of its contained water, its composition being then represented by the formula $CaSO_4, 2\,H_2O$; or, in other words,

$$\underset{\text{Lime.}}{CaO} + \underset{\text{Sulphuric acid.}}{H_2SO_4} + \underset{\text{Water.}}{H_2O}.$$

It is mostly used in building operations for small castings applied as enrichments to plaster decorations, its property of slightly expanding while setting making it capable of taking extremely sharp impressions. It is, however, soluble in water, and so can only be used in dry internal situations. It is also occasionally employed as a cement. It does not effervesce when treated with acid, and it sets with great rapidity.

The best plaster of Paris, setting quickly and hard, is made by the plasterers themselves from the raw stone. This is ground and spread in a layer some 2 or 3 ins.

deep in a shallow metal dish over a fire. When the temperature approaches that of boiling water the surface appears to rise up bodily as if suspended by the aqueous vapour given off by the lower layers; little craters are formed all over the surface and steam passes off freely mingled with fine dust; and the plaster is stirred from time to time till no further evolution of moisture takes place, as tested by holding a cold plate over it to condense the steam, when the heat is withdrawn and the plaster is ready for use.

SIRAPITE is a species of plaster of Paris similarly made from gypsum impregnated with petroleum, which is found at Mountfield in Sussex and Kingston-on-Soar in Derbyshire. It is now largely used either in addition to or in place of chalk lime for ordinary plaster work, being easy to work and rapid in setting, so that a room can be rendered one day and finished the next (two coats only being needed), while the resulting surface is hard and smooth, with no risk of bubbles forming.

It should be mixed in small quantities at a time, and should not be used upon permanently damp walls, such as retaining walls and basement walls where there is no efficient damp-course. It will keep some time in a perfectly dry store; but it is better to use it fresh from the works. If it has been kept, or the age is unknown, it should be tested before using in bulk. The work should be thoroughly dry before being decorated upon.

The following are the makers' directions for using Sirapite plaster:—

To be mixed in a banker like ordinary cement.

For first coat on walls, one measure of Sirapite to two or three of good clean sand.

For first coat on lathwork, two measures of Sirapite to one of good clean sand. Any laths will do, but for economy of material, sawn laths nailed $\frac{1}{4}$ in. apart are preferable.

Finish to be applied neat as soon as the first coat is sufficiently firm. Many users mix the finish in a pail.

A small proportion of well-run lime putty may be mixed with the first coat. The lime must be properly burned and thoroughly slacked.

One ton of coarse Sirapite and 5 cwts. of finish will cover from 125 to 130 yards super $\frac{3}{8}$ of an inch thick finished.

On metal lathing, for the first coat, Sirapite plaster should be mixed half and half with common hair plaster, the finish to be applied in the usual way.

Where the suction is great, as on stone walls, Sirapite plaster should be applied half and half with common wall plaster and finished with Sirapite finish in the usual way. The face of the wall should be scored and quite clean. It may also be necessary to size the face before applying the plaster.

Many users utilise Sirapite plaster for gauging common lime plaster. Used in this way the latter is so much improved that it becomes equal in most respects to the most expansive hard plasters. It makes excellent and rapid work, is fat and easy to use; and can be finished in two coats.

For walls, use Sirapite plaster half and half with common wall plaster.

For ceilings, use Sirapite plaster half and half with common lime and hair plaster.

Finishing may be in neat Sirapite finish, or the same mixed with more or less lime putty.

KEENE'S, MARTIN'S, AND PARIAN CEMENT are all hardened forms of plaster of Paris, of great use where an impervious, hard and smooth surface is required, and in skirtings, dadoes and angle staves likely to be subject to rough usage.

Keene's Cement is made by steeping the calcined stone (gypsum) in a strong solution of borax and cream of tartar. The liquor is composed of 1 part of borax and 1 part of cream of tartar, dissolved in about 18 parts of water. In this solution the plaster in the lump, as

withdrawn from the oven, is allowed to remain till it is thoroughly impregnated with the salts, when it is taken out, dried, and reburnt at a dull red heat for about six or eight hours. When cool it is ground to a fine powder and is then ready for use.

In making Martin's Cement the solution used is one of carbonate of potash, while for Parian Cement an intimate mixture of powered gypsum and dried borax is calcined and then ground to a fine powder.

GYPO is a new plaster, the method of manufacture of which has not been divulged, and for which it is claimed that it is more than ordinarily fire-resisting; that it adheres firmly to iron and other metals, no key being required; and that it may be painted or distempered within forty-eight hours.

An ASBESTOS NON-CONDUCTING COMPOSITION is made for plastering heated surfaces, the following being the maker's directions respecting it:—

No. 1.—For all surfaces of steam pipes, boilers, etc., which are to be free from grease. Surfaces must be covered when hot. Add to the dry compo sufficient water to make it into a good mortar, and apply the first coat very thin to the heated surface with the hand. When dry, other coats should be applied by the hand about half an inch in thickness, the last coat should be levelled and finished off with a trowel; when dry, the covering may be painted, or tarred if exposed to the elements.

No. 2.—For boiler and steam pipes. May be used as a covering for other boiler-covering compositions that need repair, or as a finishing coat over old asbestos compo, to which it imparts a very hard and smooth surface. Mix in a pail to a fairly thick paste, and empty on covering, smoothing off with a trowel; it cannot be remixed with water after once setting.

No. 3.—For gas and water mains, gas purifiers, tanks, stills, or constructional ironwork of any kind, where the temperature does not exceed 150° Fahr., to be applied

direct to the surface of metal. No key, netting, or wrapping needed. Mix in equal proportions with sand, in small quantities at a time, for immediate use, as it cannot be reworked with water after once setting. May be painted or tarred if exposed to the elements.

Plastering used externally is generally known as "STUCCO" if smooth, and as "ROUGH CAST" or "PEBBLE DASH" if rough.

Of these, stucco generally consists of 1 part of hydraulic lime to 3 of sand, trowelled to a smooth surface. If it is to be used as an external protective coat to a wall which is likely to be exposed to driving rain, it is frequently in two coats, of which the first is made with Portland cement instead of lime.

Rough cast is made, as a rule, in the same way as stucco, coarse grit being used in place of sand, and the surface being gone over with felt after being trowelled, so as to bring out the grit and roughen it; but an almost better effect is obtained by first rendering with hydraulic plaster, then covering this with a very thin coating of neat Portland cement, and immediately (before it commences to set) dashing on to this a mixture of grit and coloured lime, with a motion similar to that used when sowing corn by hand.

The term "stucco" is, however, also applied to any smooth plaster, carefully worked up, in order that it may be painted on.

Perhaps the smoothest and most perfect stucco ever made was that used in the old buildings of Ceylon, in which white of egg formed a principal ingredient; but its composition and method of working are not absolutely known.

NOTES FOR USERS.

Plaster is suitable for application in a thin layer on a firm backing, may be brought to a smooth surface over a large area.

The backing should be rough, in order that the plaster may adhere to it.

A backing of lathing on timber is liable to shrink and warp, causing unsightly cracks in the superimposed plaster.

Lathing, whether of wood or metal, is too smooth for plaster to adhere to it. Spaces have to be left, and the plaster pressed into the spaces, preferably mixed with hair to assist it to cling.

Each coat should partially dry before the next is applied, and all should thoroughly dry before it is papered or coloured.

Only hard-surface plasters, such as Keene's or Parian cement, should be used in skirtings, angle staves, and other positions liable to wear.

Mouldings can be "run," but undercutting must be avoided, as should also excessively variable thickness of the plaster.

Enrichments can be cast, and by attaching the castings to both sides of a hollow moulding the effect of deep undercutting is easily obtained.

Shallow trowel-formed and stamped ornament is also possible, while large enrichments can be built up by a clever modeller, but cutting is impossible.

Chapter XVI.

CONCRETE.

ANY mixture of substances such as will within a reasonable time harden into a compact mass may reasonably be called concrete, but the term is generally restricted in use to a combination of some inert aggregate, such as pebbles, broken stone or brick, with a cementitious matrix such as lime or cement. Such a material, according to its constituents and the proportions in which they have been employed, is useful for foundations, walling (especially retaining walls), damp-resisting floors, lintols, and as a filling between steel framework in fire-resisting floors, and in flat and domed roofs.

For ordinary foundations, where there is no excessive weight to carry, Lime Concrete may be used, and a suitable mixture is as follows: 1 part of ground stone or lias lime, 1 part clean sharp sand, and 4 to 5 parts broken stone, bricks, or well burnt ballast, small shingle, or slag. If unscreened Thames ballast be used, care should be taken to see that the proportion of sand in it does not exceed that of the lime.

The ingredients should be very thoroughly mixed dry, and again when water is added, which should be through the rose of a watering-can or hose, in just sufficient quantity to penetrate but not to saturate the mass.

Concrete may be made with selenitic mortar as a matrix, by using 6 full-sized pails of water, 3 bushels of selenitic lime, and 3 bushels of clean sand. These ingredients should be mixed as before in the edge runner or tub, and then incorporated with from 15 to 18 bushels of broken stone or bricks or burnt ballast, the whole being

turned over two or three times on the gauging floor to ensure thorough mixing with the ballast. When the tub is used the sand must be first mixed dry with the ballast, and the lime poured into it from the tub, and thoroughly

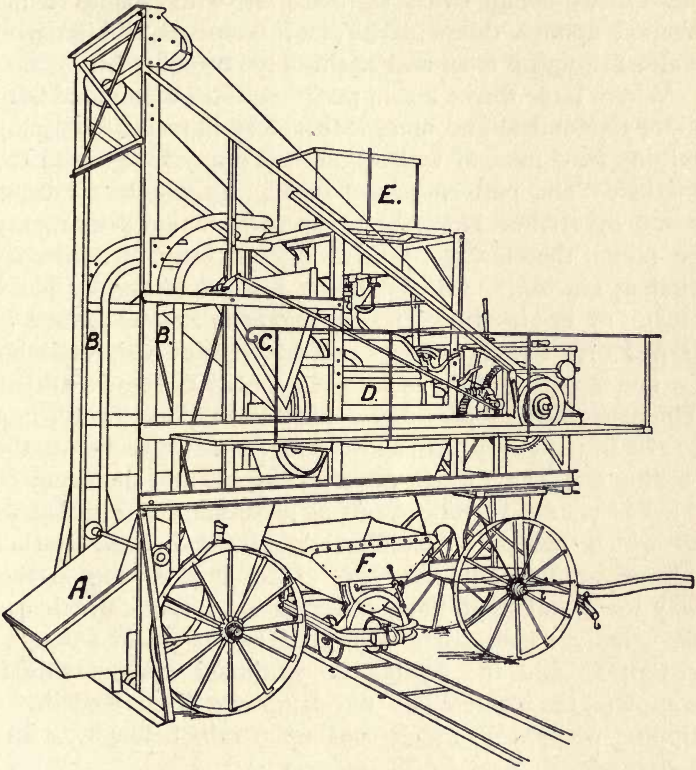


Fig. 43. Ganke's Patent Concrete Mixer.

mixed on the gauging floor. An addition of one-sixth of Portland cement will be found to quicken the setting.

It is of the utmost importance that the mode here indicated of preparing the concrete should be observed, first well stirring the selenitic lime in the water before mixing it with the sand, ballast, or other ingredient, as otherwise the cement will heat and be injured.

Where strong foundations are required, and in almost all other cases, it is essential to use Portland Cement Concrete to ensure good work. One part, by bulk, of cement is mixed with (as a rule) six of aggregate, these substances being twice turned over with spades while heaped upon a clean platform of boards, sprinkled with water through a rose, and again twice turned over.

Where large works are in progress it has been found both more economical and more satisfactory in result to employ mixing machines, of which there are many kinds upon the market. The pattern shown in Fig. 43, Ganke's Patent, made by Arthur Koppel, for use with steam power, may be taken, therefore, as illustrating one only of numerous similar machines, which can be worked either by hand, steam, or electricity. The aggregate is first shovelled or tipped into the elevator-box A, which is of a size suitable for one charge, and the measured quantity of cement added. The attendant, by pressing a lever, causes the elevator-box to rise in the slides B,B, and discharge its contents into the feeding-hopper C, which in turn passes it into the drum D. This is caused to rotate, and as it contains a central shaft to which blades or paddles are attached, the materials within are intimately mixed. After dry mixing in this way for a sufficient time, water, in an amount which can be exactly regulated, is admitted to the drum from the cistern E, and the mixing is continued. When this is complete, the contents of the drum are discharged into a tipping-waggon F, which runs upon rails below it, or into a barrow.

Concrete should not, however, at any time be thrown or dropped into position from a height, as this tends to separate the materials, the heavier particles falling to the bottom; but it should be rapidly wheeled to the site after mixing, carefully lowered into position, and spread in layers. Ramming has, to some extent, the same effect as dumping from a height, and although it is often advocated as tending to make the substance homogeneous, it ought not to be

necessary if the materials have been properly proportioned and enough, but not too much, water added.

Concrete can also be cast in moulds for many purposes, such as window sills and lintols, being then made with small aggregate and often kept under slight pressure until setting is complete. Many artificial stones, largely advertised and sold under high-sounding names, are nothing else than cement concretes.

Cement concrete should be used at once, but lime concrete may be left for a short time before being used to ensure the slaking of all the lime. It is desirable that concrete for foundations should not be built upon until it has been allowed to set for at least seven days.

Where more concrete is to be deposited on any concrete face that has become dry, such surface should be thoroughly cleaned and well wetted previous to the application of the new material.

One of the great practical difficulties which is met with upon public works is getting concreters to mix materials in small quantities just sufficient for immediate use. If large volumes are mixed at one time they can only be prevented from setting by the addition of excessive quantities of water, and this will have a most harmful effect upon the work for all time, as proper crystallization will never take place. If small quantities are used and mixed with just enough water to make them plastic and workable, a first-class concrete is obtained. It should be remembered that chemical action begins with a cement as soon as water is added, and this action is not delayed by the addition of sand or other aggregate. It follows, therefore, that cement concrete which has partially set should be thrown upon one side.

Another matter which needs careful attention is the protection of concrete from frost, and from sun and wind when initial setting is in progress, as bad effects are caused by the sun as by frost ; the latter expands the materials, and so disintegrates them, and the former robs the mixture

of the water requisite for crystallization. Work carried out under conditions of extreme cold should be protected by sacking, and the water used should be warm; or if the work is in the nature of paving, an inch of sand spread over the surface will effectually prevent any but excessive frosts from disturbing the concrete. In the case of heat, it is a great advantage to keep the face of work watered and to cover it up with damp sacking.

A properly proportioned concrete should be such that all the interstices between the fragments of aggregate are filled by the matrix, and to secure this sand is sometimes added, though it is rarely necessary with a well-broken aggregate whose fragments are of various sizes.

For ordinary foundations, especially in lime concrete, it is most usual to employ ballast, or some other pebbly substance, as an aggregate, only the larger fragments being broken so as to pass in all directions through a 2-in. ring—this last being a very necessary stipulation, constantly neglected in practice. In no case, however, can such a concrete be really good, as the smooth surface of a pebble is not one to which either lime or cement will readily adhere.

Better aggregates for walls or floors are broken stone (either limestone or sandstone), brick or slag, as the fracture is generally clean, having jagged features forming an excellent key for the cement. Round stone, that has been water-worn, is not a good material, especially where the concrete has to bear transverse strains. If gravel *must* be used, it is a great advantage to use hard, broken brick (preferably well-burnt stocks or broken burrs) in conjunction with the gravel, as a certain amount of cohesion is thereby added to the mass which would otherwise be entirely lacking. Burnt ballast concrete is the worst of any; it is impossible to obtain a thoroughly vitrified class of ballast until the cores of the ballast heaps are reached. The outsides are entirely unsuitable for use in damp positions, as the baked clay is readily acted upon by the

moisture, and gradually returns once more to its original condition.

For floors, the aggregate is generally crushed much more finely, so as to pass through a $\frac{3}{4}$-in. or even a $\frac{1}{2}$-in. ring, and for upper floors and roofs scarcely any other aggregate is used than broken brick, pumice-stone, or coke-breeze — this last being coke from which all the contained gas has not been quite extracted. It is exceedingly light, and, strange to say, is an excellent fire-resister when made into concrete with Portland cement—so much so that the British Fire Prevention Committee have definitely made up their minds that coke-breeze concrete would last in a fire better than any other. This, however, does not apply to the cheaper clinker or pan breeze, which is comparatively valueless.

The average crushing weights for concrete twelve months old, composed 1 part lime or cement to 6 parts of aggregate, is as follows, viz.:—

Description of concrete.	Crushing weight per foot super.
Grey stone lime with ballast aggregate	10 to 12 tons.
Blue lias lime with ballast aggregate	18 to 25 ,,
Blue lias lime with brick or stone aggregate	25 to 30 ,,
Portland cement with ballast aggregate	70 to 80 ,,
Portland cement with brick or stone aggregate	80 to 100 ,,

Concrete one month old, and composed of 1 part Portland cement to 6 parts of aggregate, gives approximately the following results when tested, viz.:—

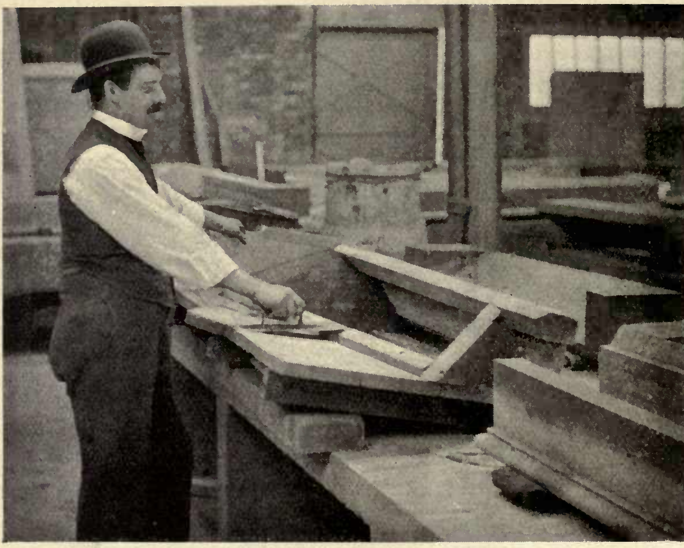
Description of concrete.	Crushing weight per foot super.
Portland cement with ballast aggregate ...	14 tons.
Portland cement with brick aggregate ...	20 ,,

The safe load for ordinary concrete (composed of 1 part lime or cement to 6 parts of aggregate) is approximately as follows, viz.:—

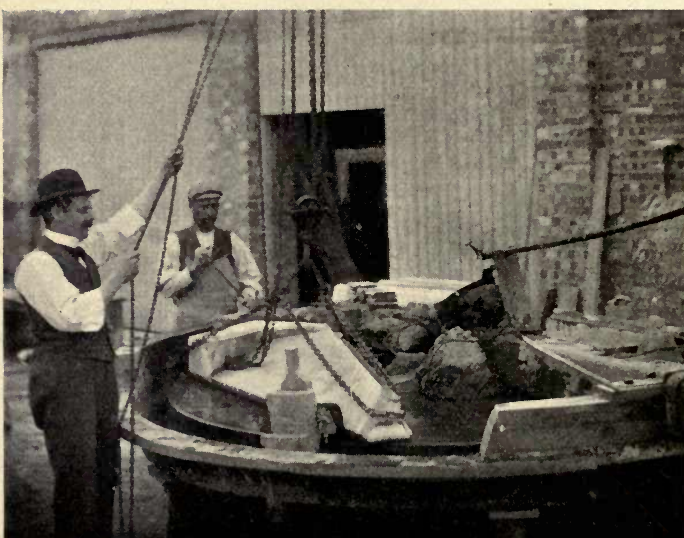
Description.	Safe load per foot super.
Grey stone lime concrete	1 to 2 tons.
Blue lias lime concrete	2 to 3 „
Portland cement concrete	6 to 8 „

The average *weight* of *concrete* (1 to 6) with different aggregates is as follows, viz.:—

Description.	Weight per foot super.	
	Lime concrete. lbs.	Cement concrete. lbs.
Brick aggregate	118	122
Limestone aggregate	130	134
Ballast aggregate	137	142



Filling the Mould for a Stair Tread.



Rubbing the Face of a Stair Tread.

WARD'S SYNTHETIC STONE

[To face p. 155

Chapter XVII.

ARTIFICIAL STONE.

THERE are three classes of artificial stones now made—Simple Cement Concretes, Cement Concretes which have been subjected to some hardening process, and Chemical Stones.

Of the simple concretes, which include Stuart's "GRANOLITHIC STONE," "GLOBE GRANITE," and Messrs. B. Ward & Co.'s "SYNTHETIC STONE" (see Pl. VI.), little need be said. Most of them are composed of a granite aggregate with a matrix of Portland cement, and are either laid *in situ* or cast in moulds for such purposes as steps and window sills. They have the advantage over ordinary concrete that they are made by the skilled workmen of firms who have a specialist's reputation to lose.

One of the simple concretes, "BASALTINE STONE," differs from the others in that the aggregate is composed of basalt chippings, while trass, a pumiceous conglomerate of volcanic origin, is mixed with the cement. It has the important property of combining with any free lime in the cement, and consequently upon this is considered to be an essential ingredient in concrete used for sea-defence work by the Dutch Government.

The hardened concretes include "VICTORIA STONE," "IMPERIAL STONE," "EMPIRE STONE," "INDURATED STONE," and others. Of these, "VICTORIA STONE," which has an excellent reputation of long standing, may be considered to be typical. The aggregate used is finely-crushed

and well-washed Leicestershire granite, having the following analysis:—

Silica (soluble)	0·55
„ (insoluble)	65·26
Alumina	13·06
Lime	4·55
Magnesia	1·01
Oxide of iron	9·81
Carbonic acid	0·03
Soda	2·34
Potash	2·85
Water, etc.	0·54
	100·00

Three parts of aggregate are thoroughly mixed with one of selected and tested Portland cement in a dry state by machinery, and the water then added in a careful manner, so as to avoid the danger of washing out any of the fine and more soluble portions of the cement; and before any initial set of crude concrete mixture can arise it is put into the moulds, in which it is carefully worked with the trowel, so as to fill up the angles and sides, thus ensuring accurate arrises all round. The moulds are made of wood, which are lined internally with metal, not only to secure accuracy of form, but also to render them durable, and proof against liability to distortion.

The moulds, filled thus, are allowed to remain on the benches of the moulding sheds until the concrete has sufficiently set, and a certain amount of the water of plasticity evaporated.

The slabs, when sufficiently dry, are relieved from the surroundings of the moulds; which, being made in pieces, can be readily detached by unscrewing the fastenings. The slabs are then taken to a tank in the silicating yard (protected from the weather), placed side by side, and covered

by a silicate solution of silicate of soda, where they remain for a period of time which depends on the condition of a slab and its capacity of absorption. About fourteen days, under ordinary circumstances, is regarded as sufficient. The slabs, after being taken from the tanks, are stacked in the storeyard, where they remain to season, and are taken away in the order of their age.

The machinery required for the conversion of the crude silica into silicate is of a very simple character, consisting of a pair of iron-edged runners to reduce the silica stone, and a series of jacketed boilers, to which steam of the required temperature is supplied, caustic soda obtained from the best sources being added.

The resulting "stone" is one of the best paving materials known, being practically non-absorbent, its porosity being only 1·3 per cent., and wearing evenly and very slowly under the tread. It has a crushing resistance of over 550 tons per square foot.

Though mostly used for pavings, it is also cast into copings, steps, balustrades, and many other forms.

The analysis of a piece of Victoria Stone paving slab is :—

Silica	50·35
Alumina	11·87
Oxide of iron	7·33
Lime	18·33
Magnesia	2·03
Potash	1·78
Soda	3·81
Carbonic acid	1·80
Water, organic matter, etc.	2·70
	100·00

"IMPERIAL STONE" is almost identical with Victoria Stone, the aggregate being washed to remove fractural dust, and so permit of closer adhesion of the cement, and

the moulds being filled upon trembling frames, while they are themselves made of stone instead of metal-lined wood, to avoid all risk of warping. The slabs are subjected to steam during setting, thereby quickening the setting process and at the same time testing the cement in a very thorough manner. They are allowed one day in which to set, and are then placed in the silicate tanks for three days, afterwards being stacked in the open for six months before being sent out.

Large pipes, as well as paving slabs, are made of this "stone," crushed flint being substituted for granite as the aggregate, and steel wire rings being bedded in them, one to every foot of length. Such pipes are well suited for many purposes, for though slightly absorbent they are almost as impervious as stoneware, and in the larger sizes, from 2 ft. 6 ins. to 4 ft. in diameter, are much more accurate in shape; and they can be easily jointed, ogee joints being used (see Fig. 44).

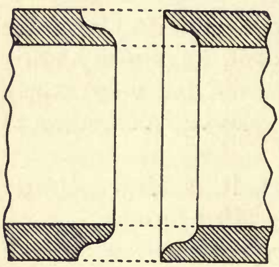


Fig. 44.

Whether anything is gained by immersion in a silicate solution is a moot point. The makers of the simple concretes deny it, while those who use this bath contend that it is advantageous to do so; and all endeavour to produce a material suited to the needs of their customers.

The "HARD YORK NONSLIP STONE" differs from other hardened concretes in having Silex York stone as its aggregate, and in being made under heavy pressure. The stone is not only crushed, but pulverised and reduced to its original sand, the ingredients are run into moulds, and a pressure of over 2,000 tons per square foot is applied, the solid slab being then immediately ready to be carried to the maturing ground, where it is exposed to the weather for at least eight months.

The only chemically formed stone of importance at the present time is Ford's SILICATE-OF-LIME STONE. It is made of silica in the form of fine sand and chalk lime in the proportion of from 92½ to 95 per cent. of silica, to from 5 to 7½ per cent. of lime, mixed dry and rammed dry into a box mould, which for the larger blocks is cylindrical in shape. The box is made of steel, and has an internal copper lining, both the steel and the copper shells being perforated.

A vacuum is created in the boxes, and boiling water introduced under pressure, causing the lime to slake and expand. As the water escapes through the perforations it is replaced by superheated steam under a pressure of 120 lbs. per square inch, thus ensuring the slaking of every particle of lime, and its combination with some of the silica, forming a cementitious silicate of lime. The whole process of manufacture only occupies eight hours, and the resulting material closely resembles a sandstone, having grains of silica cemented together with silicate of lime, either coarse or fine, or of almost any colour, according to the sand used in its manufacture.

ANALYSIS OF SILICATE-OF-LIME STONE.

Silicates	78·65
Silica	15·12
Lime	22·2
Alumina	0·98
Iron	0·75
Combined water	2·18
Undetermined matter	trace
	99·97

Perfectly homogeneous and free from flaws, it can be worked like freestone, for it is purposely not made harder than is necessary to secure perfect cementing of the particles.

It has a crushing resistance of from 600 to 700 tons per square foot, and its porosity is 8 per cent. It is consequently not very suitable, nor is it intended, for paving purposes, but for walling and general stonework, including ornamental carving. It is made in blocks, which vary from the size of bricks up to cubes of 6 ft. side.

Samples were then submitted to solutions containing 5 per cent., 10 per cent., and 50 per cent. of sulphuric, hydrochloric, and nitric acids for twenty-four hours, with the following results, which were far superior to those obtained with good weathering limestones under the same tests:—

Sulphuric Acid.			
	5	10	50
Silicate-of-Lime Stone	Unaltered.	Unaltered.	Slightly attacked.
Hydrochloric Acid.			
Do.	Unaltered.	Unaltered.	Slightly attacked.
Nitric Acid.			
Do.	Slightly attacked.	Slightly attacked.	Slightly attacked.

Chapter XVIII.

SAND—GRAVEL—BALLAST—CORE—FLINT.

THOUGH the term SAND may be applied to small grains of any mineral as found in Nature, it is generally confined in its use to those of quartz (almost pure silica), which are found in excessive abundance in the earth's crust. How very close is the approach to purity of white sand will be seen by the following analyses of samples from Messrs. J. Brown's pits in Leicestershire:—

	Rough white.	Fine white.
Water	2·68	2·00
Organic matter	0·35	0·62
Oxide of iron	0·18	0·05
Alumina and salt ...	0·76	0·67
Silica	96·03	96·67
	100·00	100·00

While a white colour is generally an indication of purity of the quartz, it may possibly be due to the presence of carbonate of lime, usually in the form of chalk, which, however, can readily be detected by its effervescence if some be placed in a saucer and acid (hydrochloric or nitric) be poured over it.

Any colour, ranging from the lightest tint of yellow to a deep red, will in almost all cases be due to the presence of oxide of iron (Fe_3O_4) as an impalpably thin coating to the silica grains, the depth of the colour being an indication of the amount of iron oxide which is present. It has no appreciable effect upon the value of the sand for building purposes, except so far as colour is of importance.

Angularity of grit, or sharpness, is generally considered an essential quality of good sand.

Fineness of grain is often also essential, especially for the finishing coats of plaster, and to secure it sifting has to be resorted to; but for coarser work it is better to have both coarse and fine particles in the sand, that the crevices between the coarse particles may be filled. Good building sand should be of pure quartz only, with grains of known sizes; for instance, such as will pass through a sieve of 900 holes per square inch, and caught on one of 1,600 holes. It is only by adopting some such specification for a sand that the best results are to be obtained in making mortar.

The presence of loam, although it renders sand easier and therefore cheaper to work, if in sufficient quantity to be detected by the touch, or the appearance, or by leaving a stain when rubbed between damp hands, is distinctly harmful, as it will irretrievably destroy even the best cementing material. It should then be removed by washing; but the effect of washing naturally good sand is scarcely appreciable, as is shown by the following tests made, on briquettes composed of 2 of sand passed through a sieve of 900 meshes per square inch to 1 of cement, by the Cement Users' Testing Association:—

	Ultimate tensile stress after two months. Lbs. per sq. in.	
	Unwashed.	Washed.
Sand from Newbury ...	430·2	430·2
Sand from Nuneaton ...	265	320
Sea sand	307	308
Furnace clinker	320	325
Standard sand	267	261
Granite dust from Rugby ...	361	356
Granite dust from Nuneaton...	350	351

The best possible way to wash sand for the removal of clay or loam is in a running stream, the force of which is just enough to remove the mud and very fine sand, leaving

the fine grit and coarser particles behind. Sand is sometimes sifted and washed by placing it in a sieve held in a tub of water. A quick horizontal motion from side to side causes the smaller grains to pass through the sieve and fall to the bottom; but much dirt is in this way carried down with the sand, so that the process is not to be recommended. It is supposed that the mud remains suspended in the water until it is poured off, and the coarse stuff remaining in the sieve is rejected as being unfit for the work; as a matter of fact, much of the mud is deposited with the fine sand, rendering it quite unfit for mixing with lime or cement.

If sand contain salt it may be removed by constant washing in running clean fresh water. The most convenient way to effect this is to construct a washing-tank in the ground, about 6 ft. square and 18 ins. deep, lined with brick in cement. The sand should be filled into this to a depth of 10 ins. or 12 ins., and a stream of water turned on it. A brown frothy scum soon rises to the surface. The sand should be constantly stirred. When the water runs off clear, and without having a saline taste, the sand may be removed for use.

It is well to bear in mind (1) that the individual grains of sand contain no salt; (2) that the salt merely coats the grains or lies between them, having been deposited there by the evaporation of salt water; (3) that the salt is soluble in water, and may be entirely removed by careful washing; and (4) sea sand so washed is quite as good for building as any pit or river sand of equal fineness and smoothness of grain.

Other methods of "killing" or neutralising the effect of the salt in sea water have been tried at various times, but they have hardly proved successful.

Salt is the most harmful substance which sand can contain. It has so great an affinity for moisture that a wall in which it is used is rendered permanently damp. Any sand which is salt to the taste, including all sea sand

and a good deal of pit sand, dug from comparatively recent under-sea deposits, should consequently be rejected for all purposes other than for use under water, unless it be first properly washed.

Sea sand is also generally rounded by attrition, and consequently wanting in sharpness; and so to a less extent is river sand. Pit sand is of all qualities, it being impossible to lay down any rule. An excellent sand is obtained in the process of washing decomposed granite for the extraction of kaolin, but it is only used locally, the cost of transport being prohibitive.

Sand does not absorb water in any appreciable quantity, its bulk is not diminished or increased by cold or heat, and does not contract in drying; therefore the greater the quantity of sand used in mortar in proportion to lime, the less probability there will be of the mortar shrinking and breaking.

In erecting new walls on the site of old ones, it is usual to work up the old mortar as sand; but this should not be allowed, as in nearly every case the old mortar, through being made with loamy sand, is valueless for the purpose, and will, if mixed with clean sand, only injure it. The use of old mortar has this to recommend it—a much smaller quantity of lime will make it into a working paste than will be required from clean sand. Road-scrapings from hard roads are frequently used with lime instead of sand to make mortar; but as the proportion of grit in them is so small, compared with the mud, horse droppings, and other filth, they do not make good mortar. Scrapings from soft roads are simply mud. Burnt clay, bricks, tiles, and soft stone are frequently broken up and ground to be used instead of sand. These, if free from dust, make a quick and fairly hard-setting mortar; but, unlike sand, they are porous, and consequently will absorb water Mortar made with them is liable to crack and shrink in drying, and where a waterproof wall is required, they should never be used instead of clean, sharp quartzose sand.

GRAVEL is an extremely coarse sand, as a rule composed to a large extent of rounded pebbles. As found in Nature it generally ranges in the same deposit from fine sand to stones of 3 ins. diameter and more, and in this condition is useful for many purposes; while for others it is "screened," or thrown against an inclined sieve having a wide mesh of strong wire. If a tolerably fine screen be first used, and then what is retained be again screened, and the process repeated three or more times, sands and gravels of several different degrees of coarseness can be separated out.

Further than this, gravel, like sand, can be washed if desired to free it from loam or clay; and an excellent WASHED GRAVEL is often obtained in this way from brick earth, being separated out in the wash mill and sold as a bye-product.

BALLAST means literally any substance of little value which is shot into a ship's hold to give it stability for a voyage when profitable cargo is not obtainable; but amongst builders the term is restricted to river gravel. This is similar to washed pit gravel, free from loam, and with its particles more or less rounded by attrition.

More smooth, and with the further disadvantage of saltness, is SEA SHINGLE, though the salt is not so pronouncedly present as it is among the finer grains of sea sand.

A form of ballast, known as BURNT BALLAST, is made by burning clay or brick earth in large heaps, the clay being unprepared in any way, but merely dug, mixed with small coal, tipped into a great heap, set on fire and allowed to burn through. In the middle of such a heap a small proportion will be well burnt to a hard clinker, which, when broken to any desired size, makes an excellent substitute for gravel for many purposes—such as for concrete and for the foundations of roads; but the underburnt portion, of which there is always much, tends to assimilate moisture and return to its original condition as a soft

clay, and so is useless. Burnt ballast is consequently a dangerous material to specify on account of the difficulty of discarding the bad lumps, which are always in excess.

CORE, or HARD CORE, is a name given to any hard rubbish, such as furnace ashes, dust destructor slag, the dry refuse from dustbins, or the detritus from buildings which have been pulled down. This is frequently used for filling up under concrete floors, it being difficult to find anything better provided it contain no vegetable or animal matter, that there be enough small stuff in it to fill up crevices and make it bind, and that it be well rammed. The size of the fragments of which it may consist is of little importance, nor their substance, which may vary from old tin trays to broken crockery and jam pots.

FLINTS, which are composed of almost pure silica, and are found in all chalk deposits, occur in curious globular and rounded shapes, and break with smooth surfaces and sharp edges. They cannot be cut with the chisel, but will break under the hammer, and a skilled workman can bring them to rectangular shape and a good face for wall facing. They resist wear excellently and make thoroughly good road metal and filling material under floors. The strange shape and the minute structure of flints show them to be mineral aggregations which were formed round a nucleus of decaying organic matter. Certain organisms, such as sponges and diatoms, provide themselves with silicious skeletons or coverings, the material for which they obtain from the water, and these organisms when decayed furnish silica for the flints. Flints, therefore, grew in the chalk after it was deposited as mud, and they did so by the gradual accretion of silica in an amorphous condition which had previously been held in solution by the sea-water in which the chalk mud was deposited.

Chapter XIX.

BRICKS: THE PRINCIPAL VARIETIES—FIRE-BRICK—EARTHENWARE AND STONEWARE—TERRA-COTTA—NOTES FOR USERS.

BRICKS are small artificially made building blocks, usually, though not invariably, made of clay in moulds, and raised to a high temperature, with the effect that the soft clay is converted into a hard material, which wears and weathers well, the silica and alumina of which, together with water, oxide of iron and carbonate of lime, the clay is composed combining in very complex manner.

As different clays vary greatly from one another, no two being alike, it is not possible to give a general analysis; nor will analysis always denote how the clay will behave during brickmaking. This can only be determined by experiment, which is often extremely costly. Roughly speaking, however, the alumina gives the plasticity necessary to enable the clay to be moulded; the silica prevents undue hardness and shrinkage; the oxide of iron helps to bind the brick and is its principal colouring ingredient; and the carbonate of lime is a binding material. The plasticity also depends upon the water. That with which the clay is mechanically combined can be expelled at a temperature slightly above 212° Fahr. without detriment to its plasticity; but the whole of the water in the clay cannot be driven off without raising the temperature to dull redness, and the clay under these circumstances loses its plastic properties, nor can it be made to re-combine with water so as to recover its plasticity—thus, for example, powdered brick will absorb a great deal of water, but it does not by such absorption regain the plasticity possessed

by the clay of which the brick was made. Of late it has become customary to add about an ounce of carbonate of barium to every cwt. of clay intended to be made into bricks to prevent discoloration, and the appearance of surface scum.

One of the chief causes of scumming is the presence of soluble salts in the clay itself, and also in the water used for tempering purposes. These soluble salts, by the combined action of the water and heat are driven to the surface of the brick, and cause the white discoloration called scum. The majority of these salts are Sulphuric Acid Salts, the principal one being sulphate of lime or gypsum.

Now, if sulphate of lime and carbonate of barium are brought together in the presence of water and heat, a chemical change takes place, and insoluble sulphate of barium and insoluble carbonate of lime are formed, thus :—

Sulphate	of Lime,	or	Ca	So_4
Carbonate	of Barium,	or	Ba	Co_3

and in this way the soluble gypsum and scum causing impurity becomes changed and rendered harmless.

Sulphate of Magnesia would be decomposed in a similar manner.

A thoroughly good brick should be regular in shape, texture and colour, equally and perfectly burnt right through, free from all cracks and flaws, even though they be hair-cracks, and sharp in the arrises ; and should give out a clear ringing sound when struck either with a stone, other bricks, or metal. For many purposes, however, it is unnecessary to insist upon all these qualities. Any hard and well-burnt brick will suffice for foundations and for internal work which is to be subsequently covered ; and for such purposes the cheaper and rougher bricks are

frequently the more useful, as affording a better key for plastering than those with a smooth surface, and often being better weight-carriers than soft, well-finished, hand-made facing bricks.

Sandy and absorbent bricks should not be used in foundations, nor in external walls where likely to be exposed to driving rain. Such bricks are generally soft and do not weather well, being frequently underburnt; and by retaining moisture they encourage the growth of lichen and climbing plants, which all gather and retain damp.

Soft, underburnt bricks are valueless. No brickmaker with a reputation to lose will sell them, preferring to pass them through the kiln a second time, or to crush them for sand.

On the other hand a markedly non-absorbent brick, heavily pressed and highly burnt, may have too smooth a face to adhere readily to mortar, especially in summer time, in spite of good wetting.

Over-burnt bricks will melt and run together, forming burrs which are useless except to be broken up for road metal or concrete.

Faulty bricks are more often met with amongst those which are hand made, hack dried and clamp burnt than amongst those which are modern machine made, chamber dried, and kiln burnt.

To tabulate the many different kinds of bricks now made in England would be an almost hopeless task. On the other hand, those which are used in London are commonly, and in a very general manner, classed as either Stocks, Flettons, Sand-faced bricks, Rubbers, Pressed bricks, Blue bricks, Glazed bricks, or Clinkers.

The term STOCK BRICK is in use in many parts of the country to denote the particular kind of brick most commonly made for general use in that particular district; but it is being gradually less and less employed in this way as machine making is supplanting hand moulding, and is becoming recognised as the generic name of a class

of brick made largely in the London district and nowhere else, from a thin superficial layer of natural clay. The London stock brick is coarse, hard and strong, and grey or yellow (or occasionally red) in colour. The fuel is mixed with the clay in manufacture, causing it to be exceedingly irregular in structure and colour, and frequently cracked; but if well burnt it is an excellent brick for general internal walling, backing and foundations, being vitrified right through, and it is frequently blue in the middle, as displayed upon fracture.

The following analyses of nominally the same earth—that from the Kentish brickfields of Messrs. Eastman & Co.—from which stock bricks of similar nature are obtained, are instructive:—

	Sample No. 1.	Sample No. 2.
Silica	77·80	69·01
Alumina	8·51	8·95
Oxide of iron	5·15	5·15
Magnesia	0·91	0·99
Alkalies, etc.	2·67	4·42
Organic matter, water and loss	3·56	6·50

Needless to say, these analyses do not discriminate between the free and the combined silica.

The following are the average results of exposing stock bricks from Messrs. Eastman & Co.'s yards (six of each kind) to gradually increasing thrusting stress, the bricks being bedded between pieces of pine $\frac{3}{8}$ in. thick, and the recesses filled with cement. The extremes varied little from the average:—

—	Stress in Tons per Square Foot.		
	Cracked Slightly.	Cracked Generally.	Crushed.
Stock brick, hand made ...	98·3	114·3	125·9
Stock brick, machine made, dried in drier, kiln burnt ...	147·3	192·5	194·7

The strength of brickwork, however, as was proved a few years since by experiments conducted by the Royal Institute of British Architects, is much less than that of bricks, and varies so largely with the quality of the mortar, and particularly with the workmanship, that no reliable data can be obtained.

The lower qualities of stocks are known as "place bricks," "grizzles" and "chuffs"; but these are local terms only, and need no definition.

FLETTON BRICKS, also known in London as FLITTERS, are machine-made and kiln-burnt bricks from an unprepared clay found in a deep bed in the neighbourhood of Peterborough, the quality and colour varying considerably according to the exact locality and the part of the bed from which the clay is obtained. They are cheaply produced in large quantities for ordinary internal work and foundations, being about as hard and strong as stocks. Though some are of a good and even red colour, most of them are khaki-coloured—a dirty grey—and so unsuited for facing. They have a peculiar and distinct grain, something like that of a coarse oölitic limestone, and a smooth surface to the grains, which are well cemented together, on which account it is sometimes thought that plaster would not adhere to them well, though in practice this objection has hardly been found to hold good.

SAND-FACED BRICKS are very largely used in London for facings. They are generally of a red and even colour, often beautiful both in tone and texture; but they are necessarily soft and absorptive, being made from a light and sandy clay, generally unpressed, or only lightly pressed, in manufacture. As a result, the lower qualities do not weather well, but pit and crumble in the course of a few years, especially when used in the lower courses of a building and subjected either to damp or wear. It is consequently necessary to carefully apply the test of tapping, to ascertain the "ring," when it is desired to use such bricks, and to reject all which sound dull; while an even

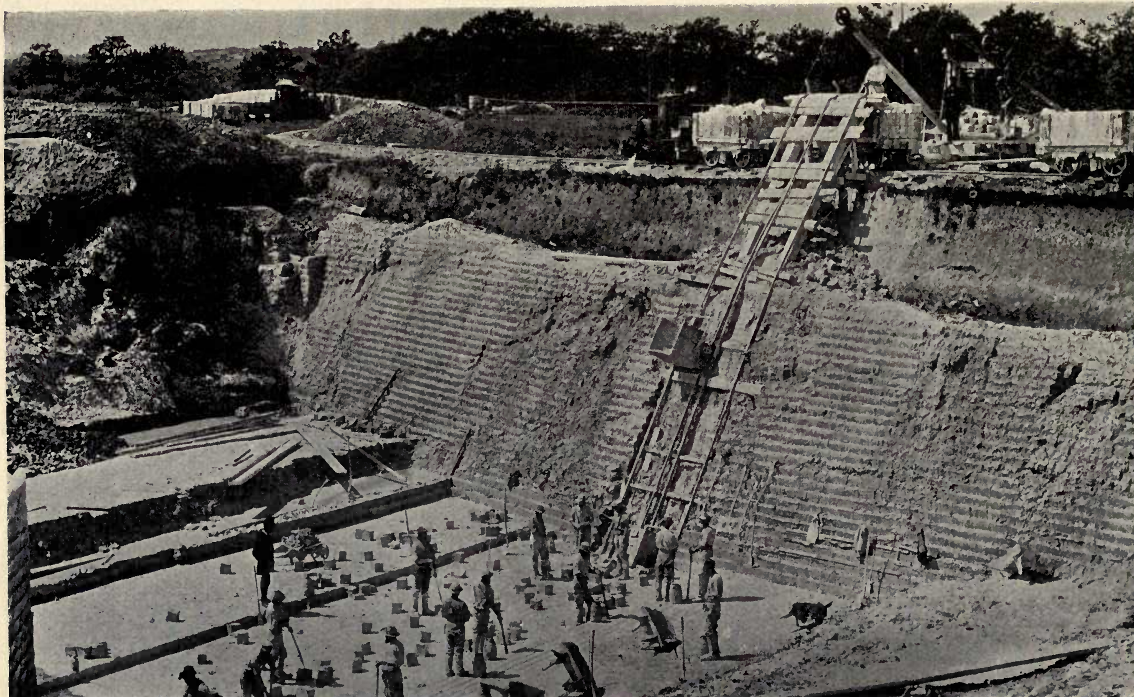
better guarantee is to use only bricks from a well-known field having a high reputation. That they are not necessarily wanting in strength is shown by the following results of tests upon six specimens of the "T. L. B." (Thomas Lawrence, of Bracknell) hand-made, red-facing bricks :—

—	Stress in Tons per Square Foot.		
	Cracked Slightly.	Cracked Generally.	Crushed.
Range	110 to 215	213 to 232	213 to 232
Average	164·2	224·2	229·3

RUBBERS are soft, sandy bricks, invariably hand made, of such a nature as to be uniform in colour throughout, and to be nearly as weather resisting if the outer skin were removed as if it were retained. Thus, as their name implies, they are capable of being rubbed down to any desired shape and to a smooth surface, and even of being carved. Both red and white rubbers are made, but the red ones are the more satisfactory, those from some well-known brickfields, such as the "T. L. B.," having a deservedly high reputation, and almost a monopoly.

PRESSED BRICKS are, if red, made as a rule from stiff, plastic clays, and if white from gault clays, the red colour of the one being caused by the presence of oxide of iron and the white colour of the other by the presence of lime. Buff-coloured facing bricks are also made from the Devonshire stoneware clays, such as those from the Marland pits near Torrington, illustrated in the accompanying photographic plate. In either case the bricks are almost invariably machine burnt, artificially dried and kiln burnt at a sufficiently high temperature to secure vitrification right through, with resulting close and uniform texture and great strength. They are also much heavier than hand-made and unpressed bricks, and so are frequently made

PLATE VII.



THE MARLAND CLAY PIT, NEAR TORRINGTON, DEVON.

[To face p. 172.

with two frogs, or else are perforated, while they are capable of being stamped with a great variety of patterns in the press.

Pressed bricks vary but little in size or shape, and have sharp arrises and a smooth surface. They are consequently suitable for all high-class work, making excellent facing, and, where their cost is not prohibitive, backing also, those which are most free from discoloration and from accidental chipping being selected for facings.

The following are the results of tests upon samples of white gault bricks made by the Aylesford Pottery Co.:—

STRESS IN TONS PER SQUARE FOOT.

Cracked Slightly.	Cracked Generally.	Crushed.
750	885	911

BLUE BRICKS are mostly made in Staffordshire, from a clay containing from 7 to 10 per cent. of oxide of iron. They are burnt at an extremely high temperature until they almost melt, and not infrequently stick together in the kiln. They are extremely hard, with a glassy surface, and of a slightly honeycombed vitreous structure. Other equally strong bricks are made, but as these carry on their face, in their deep blue-black colour and glass-like appearance, a guarantee of thorough burning, they are almost invariably used where great strength is necessary, or where they are to be exposed to heavy wear or to an acid atmosphere.

GLAZED BRICKS are of two kinds, "salt-glazed" and "dipped." To produce the former of these salt is thrown into the kiln during burning, a thin glass coating being then formed upon all exposed surfaces of the bricks, care being taken to previously protect all beds and other surfaces which it is not desired to glaze. The bricks retain their natural colour and surface, the glaze penetrating every crevice, and being extremely thin, though

absolutely one with the general structure, so that peeling is impossible. The glaze of a "dipped" brick may, however, be of quite a different colour from its general body, the brick being, as its name implies, dipped into a "slip" of specially prepared clay, either before burning or when half burnt, of such a character that a smooth face is produced, similar to that of china. The preparation of the slip is a very special matter, and great care is necessary in all the processes of drying, mixing the slip, dipping and burning, else discoloration will result, or the glaze will crack or peel, owing to its not contracting uniformly with the rest of the brick when in the furnace.

CLINKERS are small, thoroughly vitrified bricks, used mostly, if not entirely, for pavings. Of these the ADAMANTINE CLINKERS, made near Stamford, are the best known. They are of light yellow colour, machine made and pressed, and consequently heavy, dense, and almost impervious to moisture. TERRO-METALLIC CLINKERS differ from these in little else than colour, being dark brown or nearly black.

FIRE-BRICK is the name given to brick burnt from any highly refractory clay, usually one containing a large proportion of silica and little alkali, and capable of withstanding great heat. Such bricks are always highly burnt and compact in texture, and generally have a smooth-feeling surface. They vary much in quality, and are made of many shapes and sizes, according to the purpose for which they are required, some of quite moderate heat-resisting power being shaped to form fire-backs for grates; while others of an exceedingly refractory nature are made like ordinary bricks, or specially moulded to radius, to serve as furnace and chimney linings. A large amount of suitable clay is found near Stourbridge, where much of the fire-brick of this country is made, but in many other places the ordinary brick, terra-cotta and stoneware earths so nearly approximate to fire-clay that they can be used as satisfactory substitutes under moderate conditions. True fire-clay also is found in many parts of the country,

generally amongst the coal measures, and in many cases, either with or without admixture with other substances, is moulded and sold as ordinary building brick or stoneware. It is exceedingly difficult, however, to draw any hard-and-fast line, as the following table of analyses and peculiarities of three well-known clays will clearly show, for they differ widely from one another in almost every particular except the possession of the valuable quality of resistance to fire :—

—	Dinas (Glamorganshire.)	Stourbridge (Worcestershire).	Lee Moor (Devonshire).	Poole (Dorsetshire).
Silica (SiO_2) ...	97·62	63·30	74·02	48·99
Alumina (Al_2O_3)...	1·40	23·30	23·37	32·11
Potassa (KO) ...	0·10	...	0·82	3·31
Soda (NaO) ...	0·10	...	0·09	...
Lime (CaO) ...	0·29	0·73	0·40	0·43
Magnesia (MgO)	...	...	0·36	0·22
Protoxide Iron (FeO)	...	1·80	...	2·34
Peroxide Iron (Fe_2O_3)	0·49	...	1·94	...
Water (H_2O) ...	...	10·30	...	11·96
Form in nature.	Sand — to which about 1 p.c. of lime has to be added.	Stiff black clay under coal measures.	Coarser particles and refuse of kaolin or china clay, nearly white.	Clay.
Characteristics when burnt.	Resists temperature of 4000° to to 5000° Fahr. Brittle. Fracture shows coarse white particles enclosed in light yellowish brown matter.	Pale brown colour, sometimes reddish or buff, frequently mottled with dark spots. Often mixed with commonclay to resist low temperatures only.	Dull reddish brown to white. Compact, hard and refractory.	Mostly used for stoneware.

According to Dr. S. Rideal, refractory fire-clays are of two classes : (1) The silicate of alumina class, in which the alumina is about half the silica, and the latter is mostly in combined form. (2) The silicious class, in which silica predominates up to about 90 per cent., mostly in the free state, and the alumina is low.

The former class has the most plasticity for working, and is harder when burnt, but both are refractory in the

furnace, provided they contain low percentages of iron oxide, lime, and magnesia, which, especially the two former, are the cause of fusibility.

For fire-brick : (*a*) Lime and magnesia together should not exceed 1 per cent. (*b*) Iron oxide should not exceed 2 to 2½ per cent. (*c*) Both should be preferably lower. (*d*) Alkalies may reach 2½ per cent.

The following analyses are also of interest, especially as showing that two samples of nominally the same clay are not necessarily identical, the Stourbridge sample being different from that already given, and the two samples of Turton Moor clay—mostly used as "stoneware" for sanitary goods—showing a moderate amount of variation:—

	Dowlais.	Stour-bridge.	Scotch.	Turton Moor.	
				No. 1.	No. 2.
Silica	51·3	59·0	53·02	58·22	59·76
Alumina	16·9	26·2	32·01	29·46	28·56
Lime	2·6	0·3	14·02	1·07	1·03
Magnesia	1·0	1·0	0·12	0·03	0·07
Iron oxide	11·5	1·0	4·01	1·46	1·21
Water and organic matter	10·7	10·5	9·42	9·76	9·37

It is of very little use, as a rule, to build fire-bricks in mortar. They should be laid in fireclay capable of resisting as great a temperature as the bricks themselves; and under many circumstances, especially in furnace building, it is customary to build the structure of lumps of unburnt fireclay, welding it into one homogeneous mass by gradually heating up the furnace itself.

EARTHENWARE and STONEWARE are names which are often indifferently applied to clay goods of miscellaneous character, generally made from mixed earths, or of clays mixed with sand and broken pottery and stoneware. If any distinction can be drawn between them, it is that earthenware is made from milder clays, burnt at a comparatively low temperature, more or less porous, and

approximating to terra-cotta in character; while stoneware is made from more refractory clays, burnt at a high temperature, well vitrified, close grained, hard and impervious to moisture, and approximating to fire-brick. Between these two extremes, however, there is every grade and variation. As a general rule, the harder stoneware is of a light straw colour, while the softer earthenware is dark brown, but upon this point, as the others, it is impossible to be didactic. Most ware goods used in building operations, such as drain pipes, sinks, and baths, are used in connection with water, and are glazed. The glaze is itself impervious to water, but it is exceedingly thin, especially the salt glaze usually applied to pipes, so that the main substance should be as non-porous as possible; and as a salt glaze can be applied to goods when burnt at a high temperature, there is no reason why the necessary degree of vitrification should not be present when it is used. The test is by observation of a fracture, to see that it is compact throughout, and by tapping, when, if underburnt or cracked, it will emit a dull sound, while if well burnt and sound, it will ring true. Correctness of shape is, naturally, tested by observation, and is generally of importance, as warped pipes will not properly fit one another, and warping is by no means uncommon during manufacture.

Dipped glazes are thicker than salt glazes, but will rarely stand so high a temperature, so that a perfectly impervious backing is not so generally to be expected, nor is it so necessary with dip-glazed ware.

TERRA-COTTA is the name given to any burnt clay or mixture of clays which vitrifies on the face at a moderate temperature with a smooth, hardened surface, and is used in blocks as a substitute for stone, particularly in ornamental work.

So long as the outer skin remains intact it is practically indestructible by acids or weathering, and so is an exceedingly useful material for external walling in towns and by the sea-side, especially as the hard surface is sufficiently

wear-resisting for it to be used successfully at a low level upon a street frontage, while it is strong enough to carry safely any ordinary load. Its decorative possibilities are also considerable, as it can be obtained of all tints, from a light buff to a deep red, according to the proportion of oxide of iron contained in it, this reaching as much as 10 per cent. in the richer tints, and can be made of almost any shape within a limit as to size of about 3½ cubic feet.

Solid terra-cotta weighs about 122 lbs. per cubic foot, but it is generally made in hollow blocks, about 2 ins. thick, with connecting webs across the hollow spaces. In this condition it is too light for walling, and the hollows are generally filled with lime concrete, which can be trusted not to expand and burst the blocks. Projecting mouldings and cornices, however, ought not to be filled.

Most fire-clays can be made into terra-cotta, with little preparation, and then have excellent texture, colour and surface; but the interior is rough and porous when the outer skin is removed, whereas it is homogeneous and smooth in the true terra-cotta. In no case, however, ought the interior to be exposed (by rubbing or chipping, for instance, to bring down accidental irregularities), as it is by no means so wear or weather resisting as the surface.

Suitable clays for the production of terra-cotta are found near Poole, Watcombe (Devon), Tamworth, and Ruabon.

NOTES FOR USERS.

BRICKWORK.—So far as possible the standard size of a brick, with a sufficient allowance for joints, should be used as the unit for all dimensions.

Thicknesses of walls must, consequently, be in multiples of 4½ ins. (half a brick).

Lengths may, without cutting unduly, be in multiples of

$2\frac{1}{4}$ ins. (the width of a closer), though any lengths can be obtained by cutting and rubbing.

Heights should all be in multiples of 3 ins. (the thickness of a brick), to avoid the necessity of packing with pieces of tile or broken chips of brick.

Receding courses, as in footings, are preferably built in headers in $2\frac{1}{4}$-in. off-sets ; and so are corbel courses if they have any weight to sustain.

If backing and facing are of different kinds of bricks, they should be so selected in thickness as to bond properly, due allowance being made for the finer joint used in external work.

Unless there be very strong reason to the contrary, all cants, squint quoins, and bird's-mouths should be worked to the angle of 45 degrees. For all other angles the bricks have either to be rubbed or specially made.

Bricks of unusual sizes and of special contour are always to be obtained by having them specially made, but as a general rule their cost is prohibitive. Rigid adherence to such mouldings and enrichments as are easily procurable is the only safe rule where means are limited.

Keep in mind the standard sizes of the bricks you will use when planning. Thoroughly sound bond can only be secured if the distances between openings, and between cross walls, and the widths of openings, are arranged to brick dimensions. If these be not adhered to, bricks must be rubbed to fit—or are more often roughly broken and the bond destroyed.

This is particularly necessary when using hard, pressed facing or glazed bricks.

Uniformity of colour, where required, is only to be obtained by using bricks from the same maker. Thus it would be unwise to make up a group of mouldings from the catalogue sections of several different firms.

All bedded timbers should be to brick dimensions so far as they are enclosed in brickwork.

Rubbed and carved work should be so devised that all

bricks can be worked down to fit from the bricks to be used.

TERRA-COTTA.—Get out drawings full size for manufacturers—or if to a smaller scale, dimension everything exactly.

Make no allowance for shrinkage—the manufacturer will do this.

Work to the dimensions of the particular bricks you intend to use, so as to secure proper bond, allowing for the thickness of mortar joints.

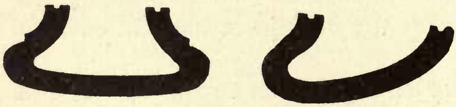


Fig. 45.

Extravagant Section (requiring separate right and left hand models).

Economical Section (the same model serving for right and left hand).

Avoid undercut mouldings and enrichments. Though possible to model, they are difficult and often impossible to mould and cast, and so have to be applied by hand and the risk of non-adherence taken; or else the manufacturer will alter your detail to make it practicable.

Keep all sweeps true, so that they can be struck from a single centre with a running mould.

Use repeats as much as possible, remembering that any variation in the size of a block, whether it be plain or enriched, will involve extra expense in the production of special shrinkage-scale drawings and a special model.

On the other hand, mouldings and enrichments can be varied in blocks of the same size by the introduction of movable sections in the model.

It is an economy to make such things as gable parapets of the same section back and front, as then the same model can be used for both right and left stop ends, mitres and kneeler blocks (see Fig. 45).

A certain amount of shrinkage and warping being unavoidable, it is unwise to design too much in straight

lines and regular curves, unless the mouldings be enriched sufficiently to render any slight twist imperceptible.

A large amount of such enrichment is possible without materially increasing the cost, as it would do if it had to be carved in stone.

Chapter XX.

BRICK, TERRA-COTTA, AND TILE MAKING.

BRICKMAKING by primitive methods is an exceedingly ancient industry, and although machinery is now used in most brickfields, the old processes of hand manufacture are still largely employed, especially in temporary brickfields of small extent, and wherever a common brick is made from a surface clay; and also in some instances where high-class bricks are made which require special personal attention in order to secure some particular characteristic. This is the case with the well-known "T. L. B." (Thomas Lawrence, of Bracknell) rubbers, made at large fields, at Swinley, near Ascot, which are required to be soft enough to be rubbed or carved, well burnt right through that surfaces exposed by carving may weather as well as the outer skin, and of uniform colour throughout their substance. At these works the clay is dug, mixed in a large wash-mill, and run into a back to dry, whence it is again dug and passed into an elementary pug-mill somewhat like a large barrel, standing upright, in which knife blades revolve on a central vertical shaft. This delivers the clay to the moulder much of the consistency of dough, nearly dry and of fine sandy grain.

The moulder has in front of him, on a rough table, a board with a raised centre (to form the frog or hollow in one side of the brick) about 10 ins. by 5 ins. in size, over which he places a wooden box or mould with neither top nor bottom, so that the bottom is formed by the board. This box he sprinkles with sand from a heap beside him. From another heap he then takes a lump of clay, kneads and rolls it for a moment, and in a single

motion lifts it and drops it into the mould, so as to fill it perfectly without pressure. Then taking a bow, having piano wire for string, he passes it over the top to cut away any superfluous clay, and this he removes by hand, leaving the top smooth. A smooth board (a pallet) is placed on this, and the mould turned over on it and lifted off, leaving the brick on top of the pallet.

Several of these "green" bricks are placed on a barrow and wheeled to a drying shed, where they are stacked with many more and left under cover but exposed to the air—to be subsequently removed to the open and piled in *hacks* or long rows with sloping boards over them to keep off the rain and the sunshine. When about half dry, they are restacked, or *scintled*, into similar rows with more air space between, about fourteen courses high instead of six or eight, as in the drying sheds and hacks.

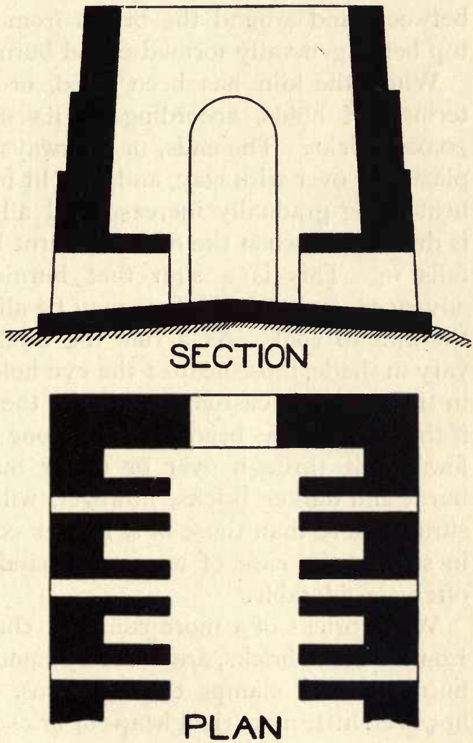


Fig. 46. Scotch Kiln.

Drying by this means occupies a considerable time, and a good many bricks are spoilt during the process by cracking, warping, or breaking, and have to be sent back to

the pug-mill and remade. The great majority, however, are passed on to be burnt in Scotch kilns. These are large chambers open to the sky (Fig. 46) with a series of fine holes down each side, opposite to one another. The raw bricks are piled up in these kilns in such a way that flues connect the fire holes, and so that the fire can pass freely between and around the bricks from bottom to top, the top being generally formed of old burnt bricks.

When the kiln has been filled, or "crowded" as it is termed, it holds, according to its size, from 30,000 to 70,000 bricks. The ends, or doorways, are bricked up and plastered over with clay, and fires lit in the fire holes, the heat being gradually increased till all contained moisture is driven out, when the fires are burnt briskly until the top falls in. This is a sign that burning has sufficiently advanced, and that the fires may be allowed to go out and the kiln to cool. As a rule the bricks will be found to vary in shade, those nearest the eye holes being the darkest in tint, and it is customary to sort them accordingly; but if the burning has been carefully done there should be but few spoilt through over or under burning. The harder burnt and darker bricks, however, will be found to have shrunk more than those of a lighter colour, the difference in size in the case of unpressed hand-made bricks being often considerable.

When bricks of a more common character, such as the London stock bricks, are made by hand, it is more usual to burn them in clamps than in kilns. These clamps are, however, little more than heaps of bricks, themselves having fuel mixed with the clay, built up with a casing of old burnt bricks to somewhat resemble a Scotch kiln, fuel in the form of dust coal being sprinkled between the layers of bricks, and fire holes and flues being roughly formed. The process is slow, extravagant and wasteful, much fuel being necessary, and the resulting bricks being exceedingly rough and unequal in quality, some being soft and valueless, and others in the same clamp so highly burnt as to have

run together into vitrified masses or burrs, useless for any other purpose than to be broken up for concrete or sold for ship's ballast.

Wherever large numbers of bricks have to be made, of good quality, it is necessary to employ machinery. This varies considerably, that which is suitable for one kind of clay being unsuitable for another, and it will suffice to describe here three different systems—that used by Mr. Fenwick Owen to produce the sand-faced "Osta" bricks from a Tertiary clay at Hill End, St. Albans; that employed by Mr. J. C. Edwards in manufacturing his hard smooth bricks from a Permian plastic clay

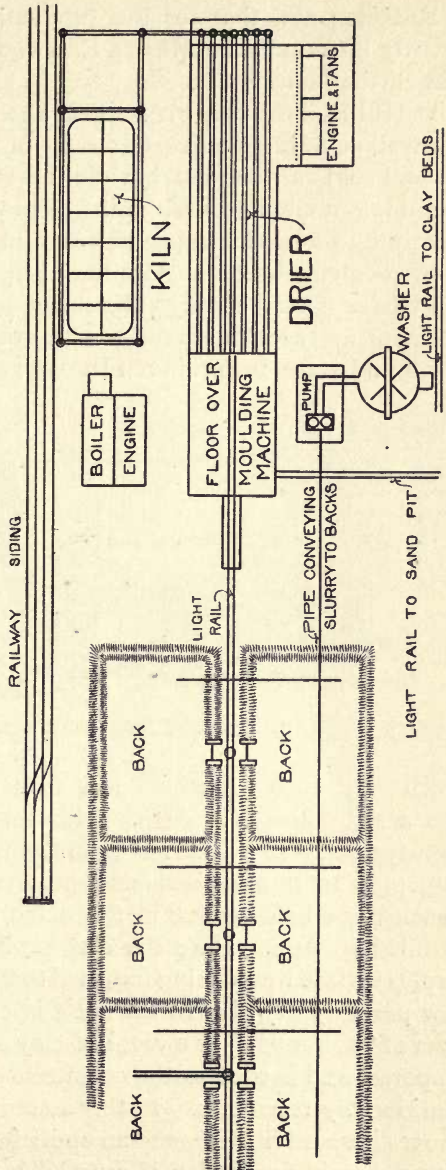


Fig. 47. Owen's Brick Works, Hill End, near St. Albans, Hertfordshire.

at Ruabon; and that for the production of stock bricks recently introduced by Messrs. Eastwood & Co., at Conyer, near Sittingbourne.

At Hill End the clay occurs near the surface, almost like a gravel, containing a great amount of flint, which is sifted out and sold as road metal, while the clay is wheeled and tipped into a circular wash-mill (see plan of works, Fig. 47) containing an ample supply of water, in which it is churned up by revolving beaters. All stones $\frac{1}{8}$ in. or more in diameter which have passed through the sieves settle in this mill as a sediment, and are cleared out once a week, the washed clay, in a liquid state, being driven through an overflow grating,

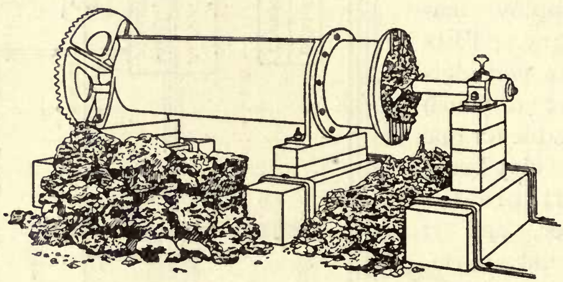


Fig. 48. Sutcliffe's Improved Pug-mill Mixer.

which only allows particles less than $\frac{1}{8}$ in. wide to pass, into a sump-hole 6 ft. deep. This thin slurry is pumped from the sump at a pressure of 20 lbs. per square inch up a long pipe to troughs, whence it gravitates to large square "backs," or hollows cut in the earth, each of which can be filled in turn. Here the clay is allowed to settle, the surplus surface water being returned to the wash-mill, and the now partially dry clay in the back is covered with a thin layer of "commons," or unwashed clay and sand, and left to evaporate and harden to the consistency of butter, which it considerably resembles. In this state it is dug out, loaded into trollies, and hauled on to an upper floor, where it is mixed with a certain proportion of crushed brick to bring it to a

proper consistency, and passed downwards through rollers to a pug-mill containing revolving knives and thence to the moulding machine in a lower room (Sutcliffe's Pug-mill Mixer is shown in Fig. 48). The moulds, each for six bricks, are made of wood. They are sanded automatically and passed into the machine where the clay is pressed into them, and as they come out are roughly "struck" by the machine, and then are hand struck to bring them to a level surface, and are lightly sanded over.

The moulds are now turned on to pallets, or boards, which lie on a revolving turntable, and the wood moulds are lifted and returned to be resanded and passed through the machine again while the pallets are transferred to racks or carriages running on rails, similar to that shown in Fig. 49, and passed into a large drying chamber. There the bricks are subjected to a constant stream of hot air forced in by fans, at carefully regulated temperatures—a low temperature when the bricks first enter the chamber, gradually altering as the carriages pass on their rails from end to end of the chamber, till a considerable heat is attained near the exit doors, each carriage, as it enters, pushing forward those in front of it on the same rails. Thus as each carriageful of raw bricks is introduced at one end, a carriageful of dried bricks emerges at the other, the time between entry and exit being twenty-two hours.

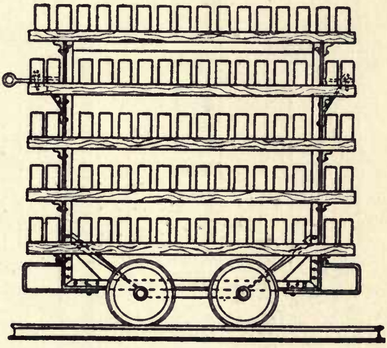


Fig. 49. Deck Carriage for Bricks.

Very few faulty bricks are found on emergence from the dryer, and these are immediately taken out and returned to the pug-mill, while the sound ones only are passed on to the kiln, which is a modification of the "Perfected" type.

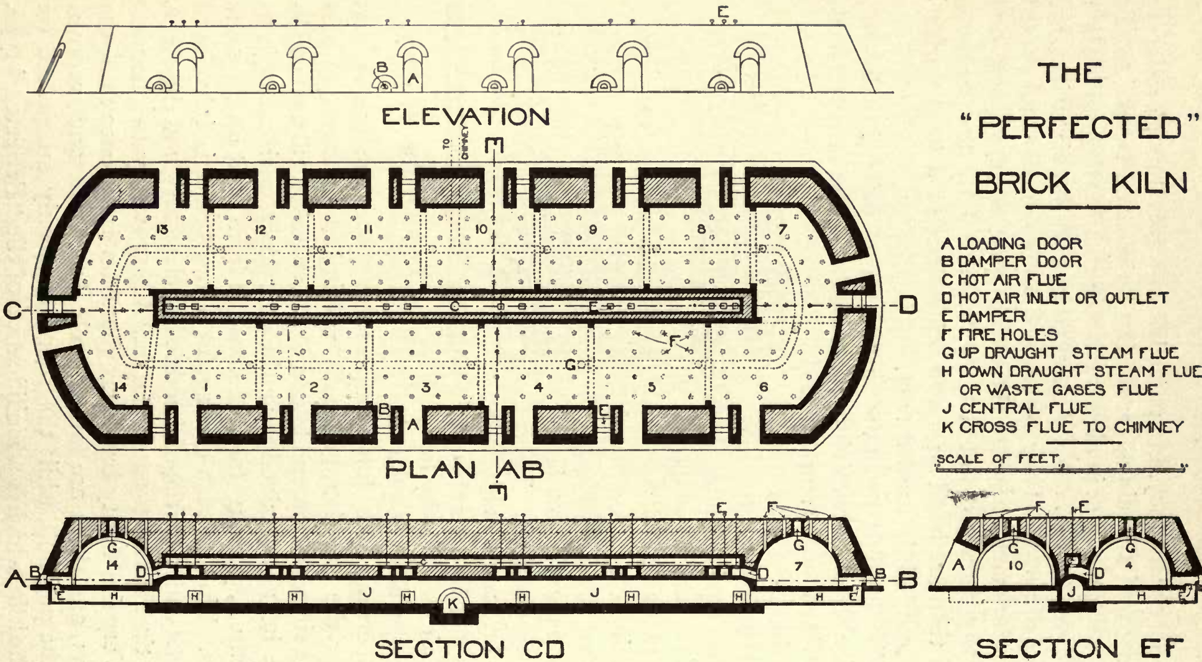

THE
"PERFECTED"
BRICK KILN
A LOADING DOOR
B DAMPER DOOR
C HOT AIR FLUE
D HOT AIR INLET OR OUTLET
E DAMPER
F FIRE HOLES
G UP DRAUGHT STEAM FLUE
H DOWN DRAUGHT STEAM FLUE OR WASTE GASES FLUE
J CENTRAL FLUE
K CROSS FLUE TO CHIMNEY
SCALE OF FEET
ELEVATION
TO CHIMNEY
PLAN AB
SECTION CD
SECTION EF

Fig. 50.

Fig. 50 shows Warren's "Perfected" kiln, which is of the improved Hoffman type, and serves the double purpose of drying chamber and kiln. If the kiln is in full working the conditions will be somewhat as follows :—Chamber 14 has just been stacked with green bricks; chambers 13, 12, 11, and 10 contain bricks in increasing degrees of dryness, while in chamber 9 the firing has just commenced; chambers 8, 7, and 6 are in full firing; chambers 5, 4, 3, and 2 are in various degrees of cooling, the bricks in chamber 2 being ready for unloading; while chamber 1 is empty.

In crowding a chamber, spaces are left so that when the chamber is fired through the holes in the top the fuel falls on to the floor of the kiln; spaces are also left between the bricks so that the heat may play all round them, while under the arches between the chambers the bricks are packed closely together so as to form a dividing wall between the chambers.

To dry chamber 14 the loading door and damper door are blocked up, and the up draught steam flue, down draught steam flue and hot air flue are opened, and the hot air passes from the cooling chambers through the green bricks, carrying away the water they contain in the form of steam. The up and down draught steam flues are built at opposite ends of the chamber so that the hot air may circulate more thoroughly. It has been stated above that the firing has commenced in chamber 9, by which is meant that the fire has been gradually drawn along the tunnel until the fuel under the first row of fire holes has ignited. The bricks round these fires become heated, and the heat gradually passes along to the next row of fires, and so on. Thus the fire creeps round the kiln, its rate of progress being regulated by means of the dampers.

With this kiln it is possible to burn seven chambers per week, or in the event of a breakdown of machinery, any less number, even down to one only.

The firing being distributed throughout the kiln enables

a very uniform brick to be produced, while only 2 cwts. of coal are used to produce 1,000 bricks.

It should be noted that the waste gas from the fuel should not be allowed to come in contact with the wet bricks, as it produces an unsightly stain.

At Ruabon the clay occurs as a hard rock in a great open quarry, whence it has to be obtained by blasting, and immediately ground to a coarse grit and stacked in the open for two months in order to weather. At the end of that time it is passed into a pan revolving under rollers for further grinding, and fed from thence to a hopper which passes it between rollers set $\frac{1}{8}$ in. apart, thence along a mixing chamber containing revolving knife blades which pass the clay forward to other rollers which actually touch, and which, though of the same diameter, travel at different speeds, grinding the clay extremely fine. At each operation a little water is added, and the action is very similar to that of a mincing machine, the clay eventually emerging through a shaped die as a plastic band—a rectangular die about $9\frac{1}{2}$ ins. by $4\frac{5}{8}$ ins. being used for ordinary bricks, bull-noses and other sections being formed by varying the shape of the die. A frame set with stretched piano wires 3 ins. apart is now drawn transversely across the ribbon or band of clay, and the separate bricks thus formed are slid on to a table on wheels and carried to the drying chambers, if only common bricks without a frog are needed, and thence to kiln. Hard, compacted bricks are made by passing them through a press before drying. The press (see Fig. 51) is somewhat like the familiar letter-copying press, with heavily-weighted horizontal arms which, on being

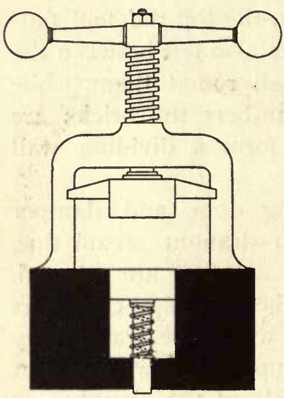


Fig. 51. Spring Press.

swung round, bring an upper die on to the brick previously slid into a sinking beneath it. This sinking has a falling bottom resting on springs with the frog or maker's name raised on it. As the upper die, either plain or with a second frog, descends, it pushes the clay and the bottom on which it rests down to a firm seating at such a depth that the entire brick is enclosed within smooth steel sides. It is thus pressed to an exact size, and as the dies accurately fit the casing it is given sharp arrises. When the upper die rises, the spring raises the lower die and the brick which rests on it up to the level, whence it is removed by hand.

Drying is at Ruabon accomplished by spare heat from kilns and from steam pipes, and the burning is in vaulted or domed kilns, similar to one another in gene al idea. The vaulted kilns are rectangular on plan and are filled from doors at the ends which are bricked up when the kiln is full. There are from eight to ten fire holes along each side, and the heat rises between the inner casing and outer wall, and passes downwards through the bricks to a perforated floor and thence to an air duct leading to a chimney (see section, Fig. 52). Each kiln is of one chamber only, which has to be independently filled, burnt and unloaded, occupying a good deal of time, but permitting of careful work.

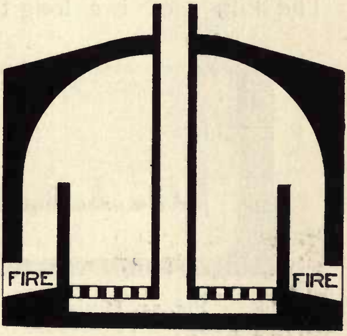


Fig. 52. Domed Kiln.

At Conyer, as in many other brickfields, the clay occurs naturally in a condition in which it is fit for conversion into an ordinary brick—in this case the well-known yellow London "stock"—without washing, grinding, or other preparation. It is dug and tipped at once, mixed with a small proportion of coal dust to act as fuel, into a pug-mill,

whence it passes directly to the moulding machine, and thence as moulded bricks to and through a long drying chamber, the operations of moulding and drying being similar to those employed by Mr. Owen at Hill End. So nearly is this the case, that, to avoid redundancy, the deck carriages and drying chamber (see Figs. 49 and 53) used by Messrs. Eastwood & Co. alone are illustrated in this chapter, those employed by Mr. Owen varying from these in minor details only and not in general principle. So thorough is the drying, that even the hygroscopic moisture is driven out, and all irregularities and superficial discolouring due to the presence of water in the kiln is avoided.

The kiln used is a long tunnel (see Fig. 54), through

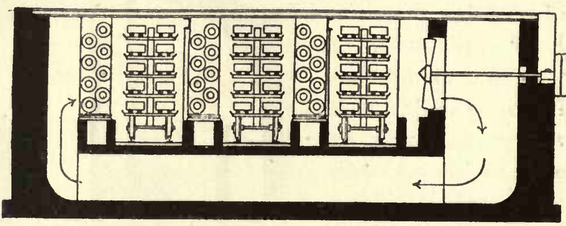


Fig. 53. Drying Chamber (Cross Section).

which a single line of rails passes. The bricks, fresh and warm from the drying chamber, are reloaded on to larger carriages and passed while still warm into the kiln, which they pass through from end to end just as they had passed through the drying chamber, each as it is introduced pushing along its predecessors. Burning takes place about the middle of the kiln, no fresh fuel being introduced, though a few " live holes " are provided in its arched top for use in case of necessity, and when the kiln is first lit. A current of air is introduced at that end of the kiln from which the bricks emerge, and passes out to a chimney shaft at the end at which they enter, thus cooling the burnt bricks and gradually heating up the unburnt until they, too, reach the temperature at which the fuel they contain ignites.

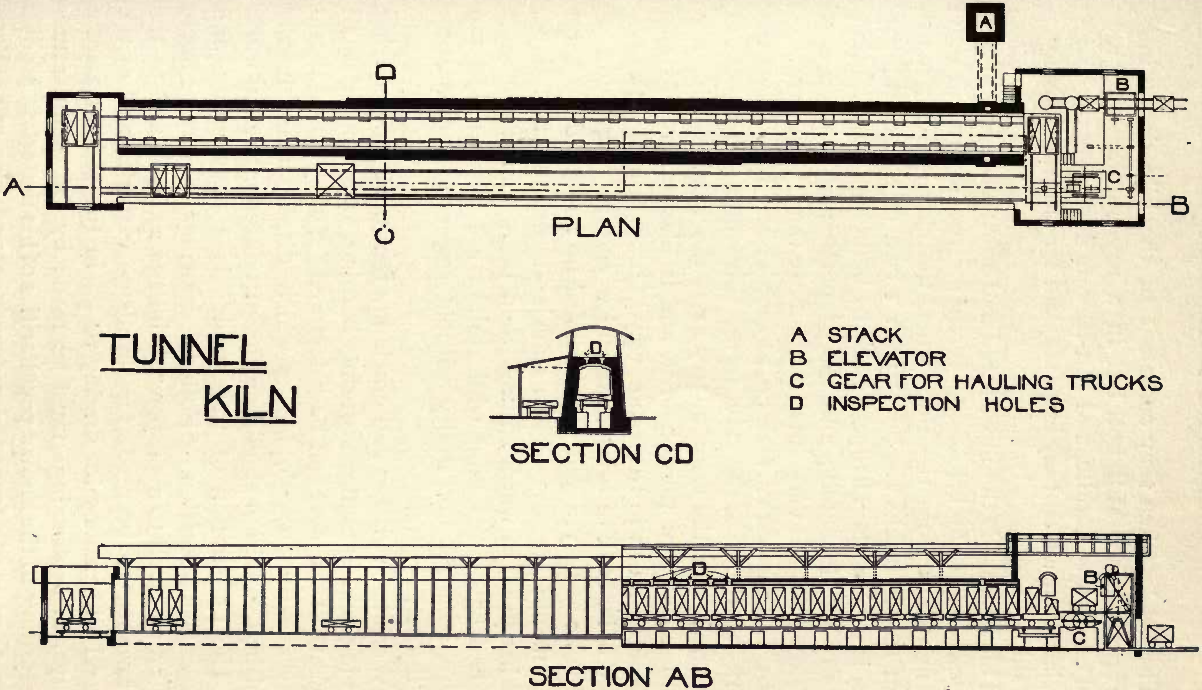


Fig. 54. Möller and Pfeifer's Tunnel Kiln.

The bricks when they come out of the kiln, direct into the open air, are still hot, but in a few minutes they are cool enough to handle, and can be run down, on the same carriages on which they were stacked for burning, to barges for shipment.

This process is the most rapid and most economical yet introduced. The bricks are ready for the market in four or five days from the time when the clay is dug; more than 10,000 bricks are burnt with 1 cwt. of coal dust; the kiln is one of the cheapest both to build and to maintain of any yet invented; and the proportion of cracked and inferior bricks is very small—not more than 5 per cent.

In TERRA-COTTA making, as seen at Mr. J. C. Edwards' works at Ruabon, the clay, in the form of a hard rock, is obtained from the same quarry as is the brick earth, only from a different portion of it, and is blasted, ground and tempered much in the same way. It is mixed with one-third of its bulk of brick dust and a certain proportion of sulphate of baryta and well kneaded up and filled by hand into moulds, removed when sufficiently dry to stand alone, further dried in warm air, and then burnt in the centre of arched or domed kilns while bricks are burnt round the sides, securing uniformity without excess of temperature to the terra-cotta.

Warping, twisting and cracking often take place during drying and sometimes during burning, and though small defects of this sort can be "doctored" if they show themselves early enough, blocks which display them in the finished condition should not be introduced into good work.

The preparation of the moulds is a troublesome and expensive operation. Full-size drawings have to be made of every block to a proper "shrinkage scale"; and as the allowance to be made for shrinkage varies from $\frac{1}{8}$ of the lineal dimensions in fireclay to $\frac{1}{20}$ in the red terra-cotta clays, these drawings must be made by the manufacturer according to the known peculiarities of his material. Models are then made from these drawings, and plaster of Paris

moulds taken from the models, the moulds being made in sections in wooden boxes, the surface of the model, and also any adjacent sides of the moulds, being smeared with soft soap to prevent adherence.

The moulds rarely survive more than one filling, but the models can be used over and over again, their life being determined by that of the material of which they are made. It thus follows that the more repeats are required from the same model, the cheaper is terra-cotta in use, especially in elaborate work, in comparison with stone ; while, on the other hand, a single object in terra-cotta is expensive.

Such objects as ridge-crestings, however, are made quite differently, being expressed through a die to the required section on the sausage-machine principle, and wire-cut to the required lengths. Ornaments are fret-cut by a bow having a piano-wire string by hand to any desired pattern, and any necessary laps are put on by hand.

TILES also are now generally expressed in thin bands, wire cut, and then pressed to any desired shape, whether they be floor or roofing tiles. The longitudinal bend of an ordinary plain roofing tile is, however, formed by hand over a leather saddle, while any nail holes are punched, also by hand. Before being pressed, it is generally necessary that tiles should be stacked for a short period under cover, close together, in order that they may recover "structure" lost in the expressing.

Embossed floor and wall tiles are made by using a sunk die in the press ; while a raised pattern leaves hollows in the tile which can be afterwards filled with a differently coloured slip, thus forming encaustic tiles. Such tiles are generally backed with a coarse clay to prevent warping. Imitation encaustic tiles are made by printing a pattern upon the surface in coloured clay.

Tiles are frequently half-burnt to "biscuit," and then dipped into plain or coloured glazes, by which means rich and decorative effects are possible. Almost all colours can be obtained, and by printing or hand-painting these can be

partially applied. Frequently when this is done several burnings are necessary for the several colours used, and extreme care in the manufacture is necessary owing to the unequal expansion of different glazes at kiln temperature and their consequent liability to crack and peel. Tiles of this nature are known as Majolica tiles.

Delicate clayware of this description is almost always enclosed within large clay jars, known as seggars, during burning, to protect it from any smoke which might injure the glaze; and the burning is accomplished in domed kilns, in which the temperature is under almost perfect control,

Chapter XXI.

BRICKS, TILES, PIPES, ETC.: THEIR MOST COMMON SIZES AND SHAPES.

BRICKS are made of many different shapes and sizes, but for ordinary rectangular bricks the following standard size has recently been agreed to by the Royal Institute of British Architects and the Brick Makers' Association :—

"1. The length of the brick should be double the width, plus the thickness of one vertical joint.

"2. Brickwork should measure four courses of bricks and four joints to a foot.

"Joints should be $\frac{1}{4}$ in. thick and an extra $\frac{1}{16}$, making $\frac{5}{16}$, for the bed joints, to cover irregularities in the bricks. This gives a standard length of $9\frac{1}{4}$ ins. centre to centre of joints.

"The bricks, laid dry, to be measured in the following manner:

"A. Eight stretchers laid square end and splay end in contact in a straight line to measure 72 ins.

"B. Eight headers laid side by side, frog upwards, in a straight line to measure 35 ins.

"C. Eight bricks, the first brick frog downwards and then alternately frog to frog and back to back, to measure $21\frac{1}{2}$ ins.

"A margin of 1 in. less will be allowed as to A, and a half-inch less as to B and C.

"This is to apply to all classes of walling bricks, both machine and hand made."

This determines the standard size of a finished brick to be $9 \times 4\frac{3}{8} \times 2\frac{11}{16}$ ins., with a slight allowable variation. Whether this can be rigidly enforced in the case of the

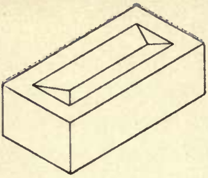


Fig. 55. Ordinary Brick.

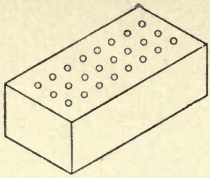


Fig. 56. Air Brick.

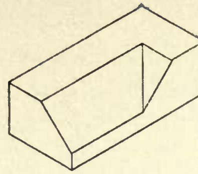


Fig. 57. Internal Plinth Brick.

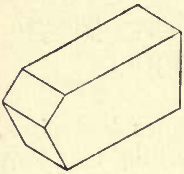


Fig. 58. Squint.

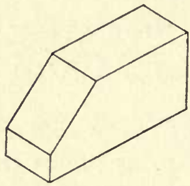


Fig. 59. Jamb.

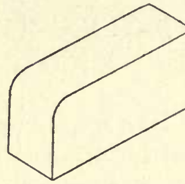


Fig. 60. Bull-nose.

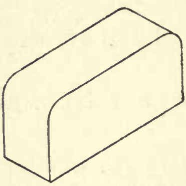


Fig. 61. Double Bull-nose.

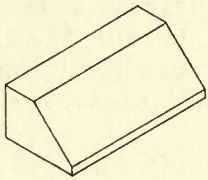


Fig. 62. Stretcher Plinth, also Headers.

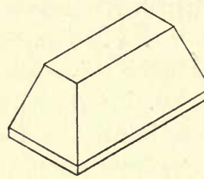


Fig. 63. External Plinth Angle.

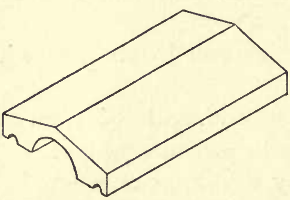


Fig. 64. Saddle Back Coping.

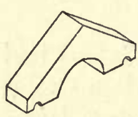


Fig. 65. Sharp Back Coping.

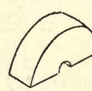


Fig. 66. Half-round Coping.

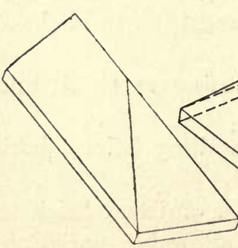


Fig. 67. Stop End for Sharp Back Coping.

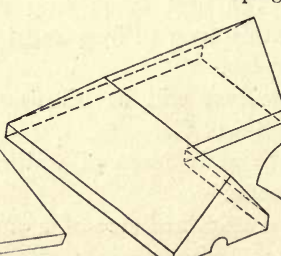


Fig. 68. Angle for Sharp Back Coping.

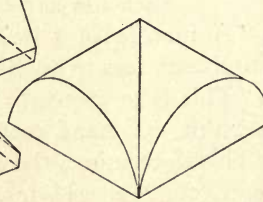


Fig. 69. Angle for Half-round Coping.

softer hand-made bricks is open to question, as the same clay from the same mould and burnt in the same kiln will, if unpressed, give bricks which vary much more than this in size, according to the position in the kiln which they may have occupied during burning.

Most bricks are made with a "frog" or hollow on the upper surface, as a key for the mortar joint, but some heavy bricks are made with two such hollows, on upper and lower surfaces, or are even perforated, to reduce their weight, and some inferior bricks have no hollows at all.

The weight of such bricks varies from 2 tons 13 cwts. per 1,000 for soft hand-made bricks, up to 3 tons 5 cwts. per 1,000 for those which are machine made and pressed.

The illustrations on p. 198, Figs. 55 to 69, show the usual shapes in which bricks of all descriptions are obtainable.

The possible variations are, however, endless, as is testified by the many catalogues of moulded and enriched bricks issued from the larger brickfields.

The regular stock size for "T. L. B." rubber bricks is $9\frac{3}{4} \times 4\frac{5}{8} \times 3\frac{1}{8}$ ins., or sufficiently large to be easily rubbed square and true to the size of a London building brick, and they weigh 4 tons 2 cwts. per 1,000; but some larger sizes are also made which are very useful for arches, particularly for key or centre bricks, viz.: $12\frac{1}{2} \times 4\frac{5}{8} \times 3\frac{1}{8}$ ins., $14\frac{1}{2} \times 4\frac{5}{8} \times 3\frac{1}{8}$ ins., $16\frac{1}{2} \times 4\frac{5}{8} \times 3\frac{3}{4}$ ins., $12\frac{1}{2} \times 7\frac{1}{2} \times 3\frac{1}{8}$ ins., and $9\frac{1}{2} \times 9\frac{1}{2} \times 3\frac{1}{8}$ ins. Such bricks are usually, if not invariably, made without frogs.

PAVING BRICKS, while sometimes plain, are usually of one or other of the patterns shown in Figs. 70 to 77, in which are also illustrated some common forms of channel and gutter bricks.

ROOFING TILES, whether used upon roofs or as tile-hanging, usually consist in England of what are known as *plain tiles*, *i.e.*, flat thin slabs of burnt clay, slightly bent longitudinally, and either provided with nibs (slight projections on the underside) so as to hang on the laths, or else

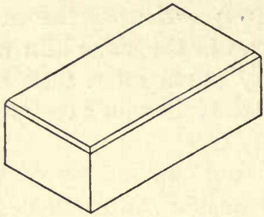


Fig. 70. Chamfered Clinker.

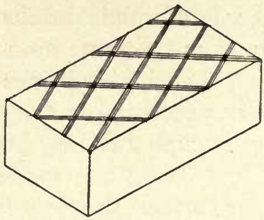


Fig. 71. Diamond Paving Brick.

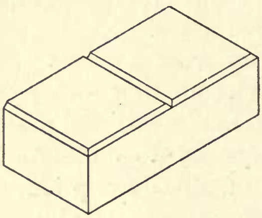


Fig. 72. Two-panel Paving Brick.

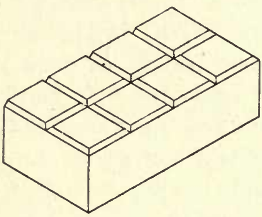


Fig. 73. Eight-panel Stable Brick.

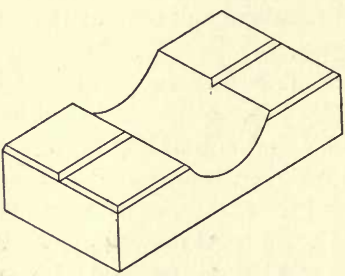


Fig. 74.—Channel to work with Two-panel Paving Brick.

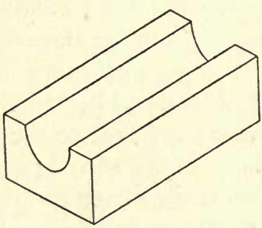


Fig. 75. Gutter Brick.

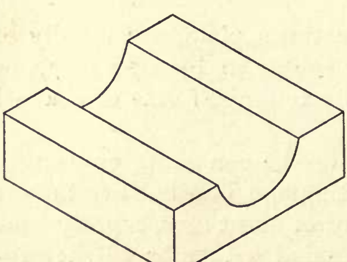


Fig. 76. Channel Brick.

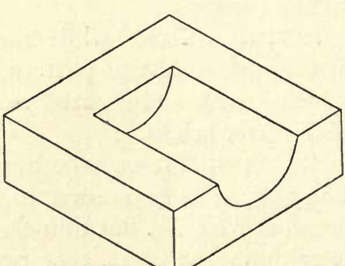


Fig. 77. Stop End.

holed for pegs or nails, or often with both. The tails, or lower ends, can be cut into a variety of patterns, though they are more often left square. The usual shapes and

Fig. 78. Plain, 10½ ins. × 6½ ins.

Fig. 79. Fish Tail, 10½ ins. × 6½ ins.

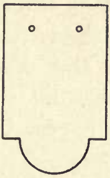


Fig. 80. Club End, 10½ ins. × 6½ ins.

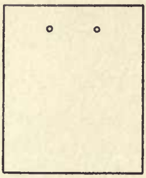


Fig. 81. Tile-and-Half, 10½ ins. × 8¾ ins.

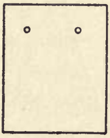


Fig. 82. Eave, 8 ins. × 6½ ins.

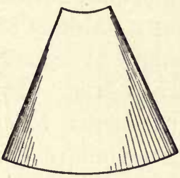


Fig. 83. Hip.

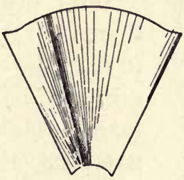


Fig. 84. Valley.

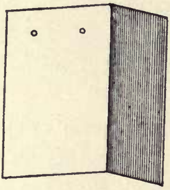


Fig. 85. Angle.

sizes are shown in Figs. 78 to 85. The angle tiles are intended for vertical tile-hanging only, while hips and valleys are only made to certain common angles, and, in fact, a really satisfactory valley tile has never yet been designed. Tile-and-half tiles are used at verges. The roofs on which plain tiles are laid should have a pitch of at least 45 degrees.

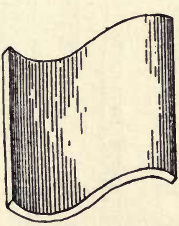


Fig. 86. Pantile.

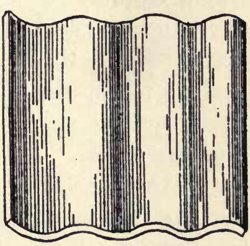


Fig. 87. Corrugated Tile.

For the roofs of sheds and temporary buildings, *pantiles* and *corrugated tiles* are much used, roughly bent to the

shapes shown in Figs. 86 and 87. They have a handsome appearance but are difficult to make wind-tight, and are easily stripped off by a high wind. They can be laid to as low a pitch as 25 degrees.

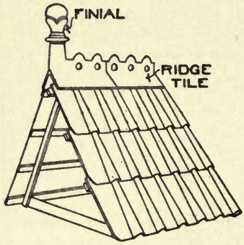


Fig. 88. Roman Tile.

A variation of the corrugated is the *Roman tile*, illustrated in Fig. 88, which, being more carefully made, is suitable for better roofs. This illustration also shows the method of hanging with nibs, and includes a ridge tile with cresting, and a finial.

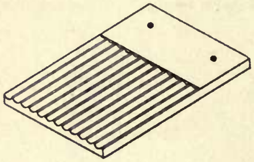


Fig. 89. Watson's Flute-faced Tile.

With ordinary flat-surface tiles there is so great a liability for wind to strip the roof, or at least to drive rain up between the tiles, that many different forms have been patented with a view of overcoming these defects, most of which make handsome as well as water-tight roofs, though they present difficulties at the hips and valleys which cannot easily be overcome except by close-cutting and the use of soakers; though in some cases special ridges and hips are made.

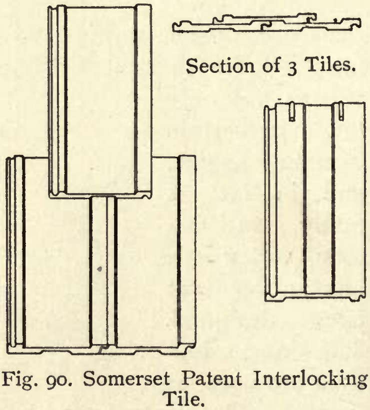


Fig. 90. Somerset Patent Interlocking Tile.

Of these special tiles, perhaps the most simple is Watson's Flute-faced tile, shown in Fig. 89, about which it is claimed that any rain beaten up along the exposed fluted surface is stopped where the flutes cease.

The Somerset Patent Interlocking tile (see Fig. 90) is

made so as to lock and fit accurately, and it is claimed for it that it may not only be used safely in the most exposed situations, but that it is much lighter than plain tiling, consequently needing less timber to carry it, and that it is cheaper even than slates. The tiles are made $15\frac{1}{2}$ ins. × 8 ins., to give a 3-in. lap with tiling laths $12\frac{1}{2}$ ins.

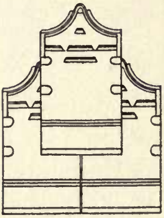


Fig. 91. Plain Tiles.

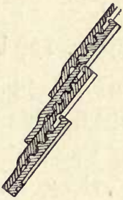


Fig. 92. Section of Tiles at Eaves.

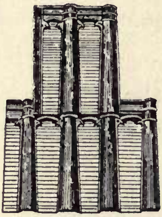


Fig. 93. Double Roman Pattern.

Fig. 94. Special Ridge.

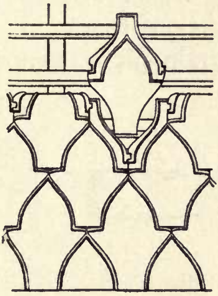


Fig. 95. Interlocking Tile (Welbeck Pattern).

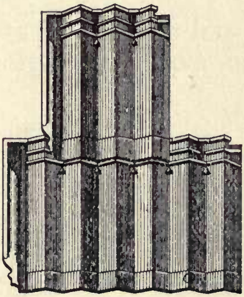


Fig. 96. Angular Pattern.

apart top to top. Under these conditions 160 tiles are required per square of 100 ft., and 500 tiles weigh one ton. Glass tiles are made to match.

Major's Interlocking tiles are made to fix without nails in four patterns, Plain, Double Roman, Angular, and Welbeck, all of which are illustrated in Figs. 91 to 96. The section is of the Plain pattern, showing flat bearing at lower

end of the tiles, which prevents wholesale breakage by workmen passing over the roof, and the ribs and fillets that stop wind and rain from passing underneath.

	Double Roman.	Angular.	Plain.	Welbeck.
Number of tiles to a square of roofing	75	90	500	275
Comparative weight of square ...	6 cwts.	6 cwts.	10 cwts.	$6\frac{1}{2}$ cwts.
Gauge	15 ins.	$13\frac{3}{4}$ ins.	$4\frac{1}{2}$ ins.	

Besides the ordinary forms of ridge, which cannot be adjusted to variations of pitch, there is one known as Pascall's Patent Expanding ridge, which is adjustable and can be used either for hips or ridges. It is illustrated in Fig. 97. The tops and wings are each 1 ft. long, and a length of 250 ft. weighs one ton.

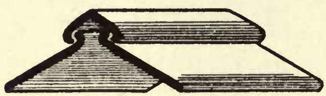


Fig. 97. Patent Expanding Ridge.

The most general forms of drain pipes, connections,

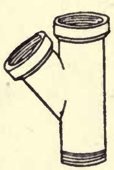


Fig. 98. Single Junction.

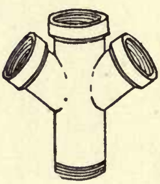


Fig. 99. Double Junction.

Fig. 100. Taper Pipe.

Fig. 101. Rest Bend.

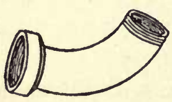


Fig. 102. Bend.

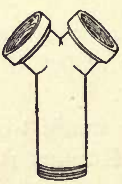


Fig. 103. Breeches Junction.

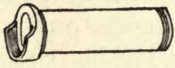


Fig. 104. Half-Sockets.

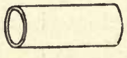


Fig. 105. Butt Pipe.

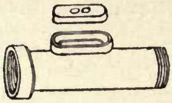


Fig. 106.
Access or Capped Pipe.

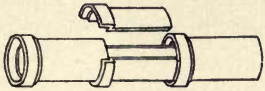


Fig. 107.
Opercular Pipe.

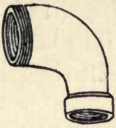


Fig. 108.
Taper Bend.

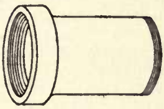


Fig. 109.
Socketted Drain Pipe.

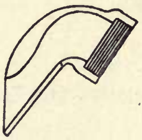


Fig. 110.
$\frac{3}{4}$ Round Bend.

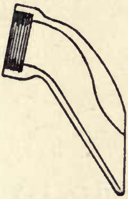


Fig. 111.
$\frac{3}{4}$ Round Bend.

traps, gulleys, etc., are shown in Figs. 98 to 111; but there are also many patent forms upon the market, each of which has its own special advantages.

Drain pipes are generally salt glazed. Usual sizes : 2 ins., 3 ins., 4 ins., 6 ins., 9 ins., 12 ins., and 15 ins. diameter (internal). Usual lengths : Smaller pipes, 2 ft.; larger pipes, 2 ft. 6 ins. and 3 ft.

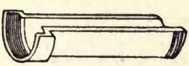


Fig. 112. Socketted Half-Channel.

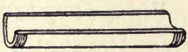


Fig. 113. Unsocketted Half-Channel.

Fig. 114. Taper Channel.

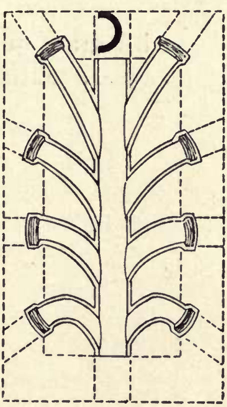


Fig. 115. Complete Manhole Base.

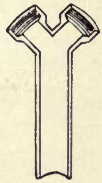


Fig. 116. Breeches Channel.

Figs. 112 to 116 show channel pipes for manholes, either white glazed internally or salt glazed.

All sizes to fit pipes.

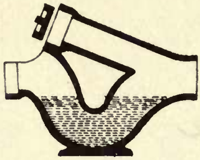


Fig. 117.

Fig. 118.

Intercepting Traps.

Figs. 117 and 118 illustrate intercepting traps (generally salt glazed), made in all sizes to fit pipes.

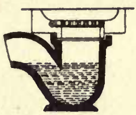


Fig. 119. Gulley with Stoneware Top.

Fig. 120. Ordinary Rain-water or Yard Gulley.

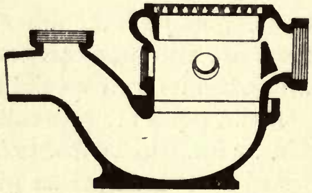


Fig. 121. Winser's Grease Gulley.

Figs. 119, 120, and 121 illustrate gulleys (generally salt glazed), usually with 6-in. square grating, and 4-in. outlet.

Chapter XXII.

ARTIFICIAL BRICKS AND MISCELLANEOUS WALLING SUBSTANCES.

BUILDING blocks of the same size as ordinary bricks are made of several other substances besides burnt clay, mostly for rough work and hard wear.

CONCRETE BRICKS are made by many firms, and vary from lime and pebble to Portland cement and granite chippings in composition. They can be made very cheaply by unskilled labour, and would probably come into general use, especially in districts where the raw material is readily obtainable, if from any cause the price of clay bricks were to materially increase. They are largely used in some parts of Europe, for backing to stonework, foundations, cross walls, and for external walls which it is afterwards intended to treat with stucco, for which they afford an excellent key if a pebbly aggregate be used.

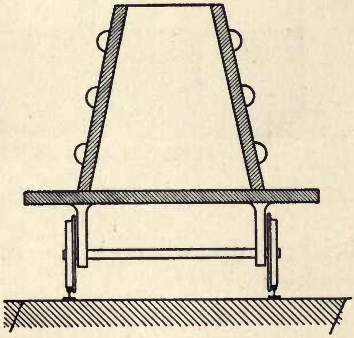


Fig. 122. Jacket on Bogey.

ARTIFICIAL STONE BRICKS are made by some of the firms that manufacture artificial stone, and partake of the same characteristics (see "Artificial Stone").

SLAG BRICKS are made directly from the slag from blast furnaces. As manufactured by the Tees Scoria Brick Co., at Middlesbrough, the slag, as it is run from the furnace,

is poured into iron "jackets" (see Fig. 122), which have no bottoms, but rest on the iron table of bogeys, all joints and the outlet being pugged with clay. The bogeys are wheeled, when full, with the aid of small locomotives, in front of a large horizontally revolving wheel, attached to the circumference of which are a number of cast-iron moulds, into which the slag is poured from the jacket in rotation. As the wheel revolves, the bricks cool sufficiently for the moulds to be opened so that they drop out, the moulds being then ready to be refilled as they again pass in front of the jackets; while the bricks are thrown without fuel into an annealing oven (Fig. 123), whose doorway is

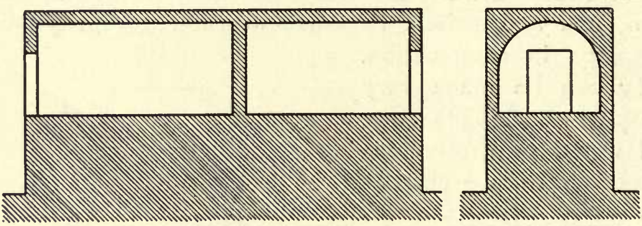


Fig. 123. Pair of Annealing Chambers back to back.

bricked up when it is full, and there left to cool gradually.

The bricks produced are hard and heavy, glassy in structure, cream-coloured externally, and blue on fracture. They are used for paving purposes, especially for street crossings, while curbs and channels are also cast. Unfortunately they often contain bubbles, but they are absolutely impervious to moisture and admirably suited to resist wear. The moulding is rough, and many of the bricks are spoilt in manufacture.

GLASS BRICKS have also been occasionally cast in a somewhat similar manner, for use where translucency was required, but they are too slippery for paving purposes and too smooth to adhere to the mortar in walling.

FIXING BLOCKS are bricks made of a soft breeze concrete, into which nails can be driven for the attachment of joinery. They have the advantage over wood plugs of being non-inflammable, and should consequently be preferably used in chimney breasts and other positions where wood plugs might be liable to catch fire.

TERRA-WODE BRICKWORK, made by Jabez Thompson, of Northwich, seems to consist of burnt clay, in which cork dust or some such substance has been mixed, with the

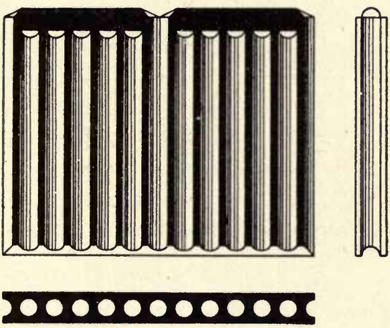


Fig. 124. The London Fireproof Plate Wall Company's Partition.

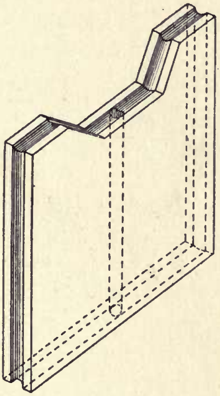


Fig. 125. Acton Concrete Partition.

result that it has been burnt away in the kiln, leaving a series of small cavities. The resulting brick is very light in weight, while the cavities render it sound proof, making it a useful material for single-storey partitions under many circumstances, especially as it is comparatively fire resisting, while nails can be driven into it as into breeze fixing blocks.

CONCRETE PARTITION SLABS are made by several firms, with the object of obtaining exceedingly thin and at the same time fire-resisting partitions which can be quickly built, while their surface is so smooth that little

plastering is necessary. Of these, the slabs made by the London Fireproof Plate Wall Co., Limited, are rectangular (see Fig. 124), with a circular hollow through the middle of each, down which steel rods can be run to strengthen the partition if necessary, while the joints are formed in cement grouting. The slabs of the Acton Concrete Partition Co., Limited, differ from these mainly in shape, as shown in Fig. 125. For both forms the same advantages are claimed.

Chapter XXIII.

TIMBER: ITS GROWTH AND STRUCTURE—NATURAL DEFECTS—DESTRUCTIVE AGENCIES—MARKS AND MEASURES.

THE timber which is used for building purposes in Great Britain is obtained exclusively from trees which are "exogenous" in growth—that is, which grow by depositing annually a new layer of material between the previous year's growth and the bark. Besides this, almost all are "deciduous" (shedding their leaves annually), and not evergreen.

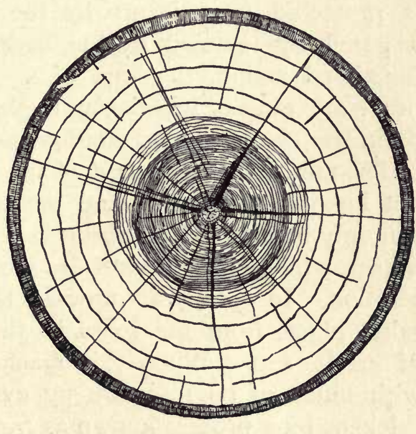


Fig. 126. Section of Tree.

When at maturity such trees consist, when seen in cross section, of a series of roughly approximately concentric rings, each graded from a dark to a lighter tone in woods grown in temperate climates having spring and summer, but homogeneous in tropical woods, these being known as "annual rings," bound to one another by radial lines known as "medullary rays"; both of which are more or less distinct, according to the nature of the timber and the circumstances under which it has been grown (see Fig. 126).

Of the annual rings, the central rod is known as the

"heart," and, together with the rings which lie nearest to it, is rarely if ever found to be straight, on the wood being cut lengthwise, even in the best and straightest timber cut from straight and apparently uniformly tapering trunks. This is due to its having originally formed the sapling, easily bent and twisted, and not stiffening into regularity of form till near maturity, when compensating growths have taken place to produce external uniformity. It is this heart which first decays in the living timber when maturity has been passed.

The rings lying nearest to the heart, known as "duramen," or *heartwood*, alone are, properly speaking, those of fully established timber; and these are easily distinguished and sharply divided from the outer rings of "alburnum," or *sapwood*. Outside the sapwood occurs a single thin ring of soft material known as the "cambium layer," which is protected from injury by the bark. If this layer is exposed by removal of the bark, so as to prevent its functional action, the tree dies. The rings nearest the heart are almost invariably thicker than those near the bark, the change being gradual across the section.

The annual rings consist of innumerable closed cells—not longitudinal tubes—and the transference of moisture can only be effected by absorption through the cell membranes, while solids cannot be absorbed at all except in solution. In spring an upward transference of moisture takes place, from the roots, in the *sapwood*, in the form of crude sap. When this reaches the leaves it parts with much of its moisture by evaporation, and the sap thickens by a process known as *transpiration*. The leaves, by an elaborate process which need not be explained here, absorb carbon dioxide (CO_2) from the atmosphere and decompose it, freeing its oxygen and retaining its carbon, which, by *assimilation*, is added to the sap. This now descends in the cambium layer, and is deposited as "*elaborated sap*" to form a new annual ring outside that deposited during the previous year. This change of

assimilated food or sap into structure is known by older writers as "metamobism," and by more recent writers as "metastasis."

Simultaneously with this growth a ring of sapwood changes into heartwood, and henceforth plays no part in the annual transference of liquid from roots to leaves—which, however, is not the only function of the sapwood, for in its cells are accumulated during summer and autumn a reserve of material, the superfluous product of assimilation, to be held during the winter for use in producing buds in the following spring.

Sapwood containing this elaborated sap is liable to attack by worms or vegetable growth in stagnant air and moisture, and it is consequently now considered best to fell timber in summer, when the rising sap consists of nothing more than water and mineral salts in solution, as obtained from the roots.

There are, however, many advocates for winter felling, while the sap is quiescent. These forget, or are unaware of, the presence of the elaborated sap at that period, or else do not recognise the liability to decay which its presence involves; but all are agreed that felling in spring or autumn, while the sap is most vigorous in its movement, should be avoided.

Chemically, normal wood fibre varies little from the formula of cellulose, $C_6H_{10}O_5$.

The medullary rays, known also as the "*silver grain*," are classified as "primaries," radiating outwards from the heart towards the bark, and "secondaries," radiating inwards from the bark towards the heart, the latter rarely penetrating beyond the sapwood. They consist of a series of flattened cells lying above one another in rows, and their function is to assist the transference of elaborated sap from the cambium layer inwards.

Owing to its structure and method of growth there are certain natural defects which are common to all kinds of timber. These should be avoided or removed, if possible,

during conversion for use. Whether timber containing them should be used for any particular purpose is a matter of degree and for the exercise of judgment in each case.

Of these, the most serious is the presence of an undue proportion of sapwood. This is not so often an inherent defect in the timber itself, as it is due to immaturity—the felling of unripe trees in order to meet an insatiable demand—and is so common now amongst European fir and pine timber that it has become difficult to find any which is fit for use in really good work. Such wood is open and spongy in grain, with large annual rings, and generally

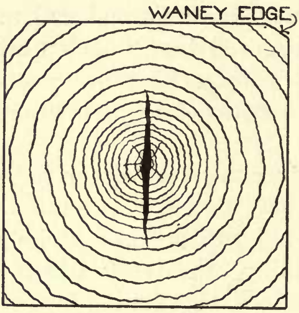


Fig. 127. Heart Shake.

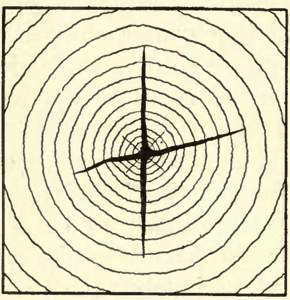


Fig. 128. Star Shake.

blue in colour, the sapwood being readily distinguished from the heartwood in almost all cases by the difference of colour. Similar defects are sometimes due to climate and soil; but, whatever may be its cause, open grained, spongy sapwood should be avoided, and for work in which permanence and high quality are of more importance than economy *all* sapwood should be removed, as it is much more liable to decay than is the heartwood.

SHAKES, or longitudinal splits, are common in all timbers, occurring in the growing tree, and sometimes developing and extending during the subsequent process of seasoning. Until the tree has been felled they are undiscoverable, and even then are sometimes difficult to detect, their

appearance varying from extremely fine cracks to open, gaping wounds. They occur more at the butt end of a tree trunk than higher up, and in most instances do not extend far. When they do, they militate much against the economical conversion of the timber, and if twisted longitudinally, as is sometimes the case, may render it totally unfit for use. They are of two classes, *heart* or *star shakes*, and *cup shakes*. Of these, the former radiate from or to the heart, occurring along the medullary rays, and the latter form rings round the heart, occurring along the annual rings (see Figs. 127, 128 and 129).

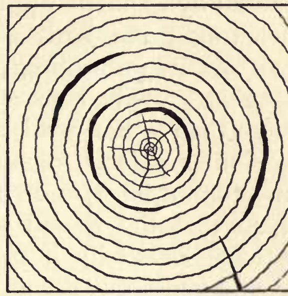


Fig. 129. Cup Shake.

KNOTS are the roots of small branches, and if few, small and well knit to the stem, are not looked upon very seriously. On the other hand, they break the continuity of the fibres and militate against the strength of the timber as a whole, while their presence may completely destroy the beauty of the grain where it is exposed in high-class joinery. Whether any particular piece of knotty timber is admissible or not is always a matter of judgment, but large or loose knots (the latter liable to fall out) should cause rejection, and so should the occurrence of several

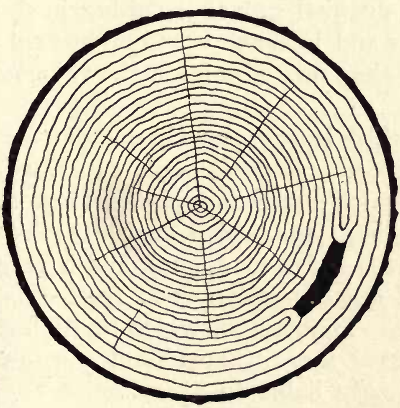


Fig. 130. Rhind Gall.

small and otherwise unobjectionable knots if close together or forming a ring round the timber.

RHIND GALLS (see Fig. 130) are more rare. They are caused by accidental injury to the growing tree, which has penetrated the bark and damaged the cambium ring, temporarily preventing growth over a limited area. Subsequent growth, however, covers the wound, which is no more than a local weak spot in the timber.

Similar defects, caused by branches having been torn away from the stem or by their being lopped too close to it, so that the wound is eventually covered, may be very serious, especially if moisture has been admitted to the wound and decay set up before it has healed. Decay thus started and enclosed may be conveyed by the sap over an entire tree.

TWISTED FIBRES, as if the tree had grown corkscrew-wise, are occasionally found, and do little harm if the timber be used in the form of masts or poles, but prevent its being cut into planks, whose strength depends mostly upon continuity of grain ; and unequal growth, resulting in the annual rings being thicker and less compacted on one side of the heart than on the other, may also lower the value of a timber.

DOATINESS is a defect which is rarely seen in timber when it is first felled, but which, for no explainable cause, will appear in it after and during seasoning in the form of numerous small, dirty-looking spots, which are softer than the surrounding wood. It is a sign of disease, and is very prevalent in the soft and quickly-grown wood from some parts of Northern Europe. Timber upon which this defect is seen should not be used for any structural purpose whatever, as it is exceedingly liable to decay.

BURRS or EXCRESCENCES are apparently the unsuccessful attempts at the formation of branches from some individual spot. When of large size they are very valuable for veneers

FOXEY WOOD is that which is disfigured by dull red stains, the forerunners of decay, and denoting growth in a marshy

soil. These stains are generally found round the heart of the tree.

QUAGGY WOOD is that which is grown on loose soil, having the centre full of "shakes" and "clefts."

UPSETS are defects where the grain appears to be partly separated, so that a shaving at that spot would bend to a sharp angle as if broken. They seem to be the result of violent winds on the more exposed trees of a forest (see Fig. 131).

CROSS-GRAINED WOOD is that in which the fibres are presented endwise or obliquely on the surface. In this arrangement consists the beauty of mahogany and other hard woods.

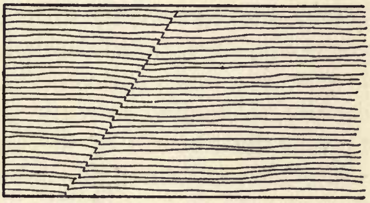


Fig. 131. Upset.

FRESH WOOD is that which, owing to the decreased lateral adhesion of the annual layers, has become brittle and short, and has lost such elasticity and adhesiveness of fibre as—in the case of the ash, for example—constitutes its peculiar excellence.

CAMBLETED is a term applied to the roots of the ash and some other trees when they are curiously veined, showing a beautiful surface when polished.

ROSY is a rare term, used to imply that the grain of the wood runs in an irregular direction or overlaps.

CURLS AND FEATHERS are the result of the confused filling in of the space between the forks of the branches.

DRY ROT is a disease in timber, occurring after it has been felled and converted for use, apparently infectious, which occasions the destruction of its fibres, and reduces it eventually to a mass of dry powder. It is produced most readily in a warm, moist, stagnant atmosphere. Water, carbonic acid gas, and probably carburetted hydrogen are evolved, and a dusty substance remains.

The growth of fungi accelerates the progress of dry rot, but the origin of the disease appears to be the incipient decomposition of the sap in wood, by which the fungi obtain a *nidus* (nest) for their growth. Doaty timber is exceeding likely to develop it, and so is immature and insufficiently seasoned timber, particularly if inserted in a damp and unventilated situation, such as in ground-floor joists where the site is not concreted nor the space below them ventilated, and in floor boards, and even in wood-block flooring, laid on damp concrete and covered with linoleum.

When it first appears, the timber swells and changes colour, and is covered with a cobweb-like fungus, which emits a musty, unmistakable odour by which its presence is generally first suspected. The fungus grows and spreads rapidly, thickening into the semblance of hoar frost and then to the likeness of the outer coating of a mushroom, while finer filaments, like leaves, spread over all adjacent timber and even over brickwork, plaster, and masonry, but only living on and destroying the woodwork, preferring that which is soft, sappy, and unseasoned.

Once established, there seems to be no cure for it. All affected parts must be cut away and burnt, and replaced by sound, well selected, well seasoned timber, properly arranged so as to remain dry and well ventilated.

DECAY in the living timber commences normally with the pith or heart, and is due simply to old age, being a sign that the timber has passed maturity. In marked examples it results in hollow trunks. It also occurs, however, as has been already noted, where branches have been improperly lopped or torn off, particularly if wet has been allowed to enter the wound.

In converted wood, however, it appears generally to attack the sapwood first, and it is greatly accelerated by insufficient seasoning and by exposure to moisture accompanied by heat and want of ventilation ; while it is retarded by hermetically sealing the pores either by charring the

surface or by periodical tarring or painting, or by any of the preservative processes to be mentioned later.

Constant exposure to wet does not seem to greatly accelerate decay, which, however, sets in very rapidly if there be exposure to alternate wet and dry, appearing in such positions as the margin where posts enter the earth, and in window sills which have had window-boxes for flowers close to them for a year or two. In such positions it is frequently called *wet rot*; but this seems to be only another name for accelerated senile decay.

Except damp and want of ventilation there are not many external agencies destructive to timber used upon land in Europe. There are a few small beetles which will burrow into old wood, making a number of small holes and eating away portions of the material softened by age. These can be destroyed by subjecting them to the vapour of benzine or chloroform. There are also three forms of destructive ants, which prey mostly upon living timber, including the DUSKY and the YELLOW ANT (*Formica fusca* and *Formica flava* respectively), which prefer soft woods, and the BLACK CARPENTER ANT (*Formica fuliginosa*), which prefers hard and tough woods.

In the tropics, however, especially in Africa, India, and Australia, the so-called WHITE ANT (properly a soft-bodied *termite*, and not an ant at all) is highly destructive. It tunnels beneath the surface of the wood, which it attacks suddenly and in great numbers, and working in silence will entirely destroy even the whole timber work of a house before its presence is suspected. It will not, however, attack the very hardest woods, such as new teak, the heart-wood of jarrah, greenheart, and ebony, while creosoted soft woods are also safe against its depredations.

There seem to be no serious enemies to timber immersed in fresh water, but on the other hand, there are several which work in salt water. Of these, the most important is the TEREDO NAVALIS, which prefers clear to muddy water, but is to be found in all climates and in nearly every

English port. It is a worm which bores into the wood, mainly along the grain, and preferably in soft timber, greenheart being that which resists it most successfully. Worms as much as 2 ft. in length and $\frac{3}{4}$ in. in diameter have been found.

The LIMNORIA TEREBRANS, minute in size and resembling a small woodlouse, is also very abundant in British salt waters, and, attacking soft timber in incredible numbers, will rapidly do a large amount of damage. This also is resisted by greenheart and by teak; soft fir has been destroyed at the rate of 3 ins. inwards per annum. It almost always works just under neap tides, and while it is destroying the surface of timber, the Teredo will be attacking the interior.

Less important, perhaps, are the CHELURA TEREBRANS, or *Wood-boring Shrimp*, which tunnels close below the surface of timber, removing it in a series of flakes; and the LYCORIS FUCATA, a little worm with legs, something like a centipede, which is an enemy of the Teredo, entering its tunnel, killing it, and then living in the home thus captured.

The best timber is, according to Dr. Anderson, obtained by felling the tree at the age of maturity, which depends on its nature, as well as upon the soil and climate. The ash, beech, elm, and fir are generally considered at their best when of seventy or eighty years' growth, and oak is seldom at its best in less time than a hundred years; but much depends on surrounding circumstances. As a rule, trees should not be cut before arriving at maturity, because then there is too much sapwood, and the durability of the timber is much inferior to that of trees felled after they have reached their full maturity.

From what has already been said of the essential difference between sapwood and heartwood, it will be readily understood that no amount of seasoning or drying will convert the one into the other.

All the same, the strength of many woods is nearly doubled by the process of seasoning. Hence it is thriftless

to use timber in a green state; especially as it is then not only weak, but liable to warp, twist, and shrink while it slowly parts with the contained moisture, as it will do eventually. To a certain extent this liability exists even in well-seasoned timber, fresh shrinkage and sometimes warping taking place whenever a fresh surface is exposed by planing, and warping being experienced if the wood be damped. It is accordingly customary to have joinery worked up and lightly wedged together long before it is needed, that any correction for such changes of shape or size may be made before the work is finally wedged and glued up.

Whole logs of timber, if left exposed to changes of atmospheric conditions, particularly to hot sunshine, are very liable to split. They should either be cut up, either into quarters or preferably into scantlings, and set to season; or else be totally immersed in water until this is convenient.

All wood darkens on exposure to light, especially direct sunshine.

Good timber should be uniform in substance, with straight fibres and annual rings of regular form and size, smelling sweet when fresh cut, even and bright in colour, with a silky lustre when planed, the strong grain appearing to rise to the surface; and it should be free from large or dead knots, shakes, spongy hearts, porous grain, sapwood, or other defects. Thus it is often specified, but in practice the absence of all defects is rarely to be met with, and discrimination must be exercised, remembering that trees will not necessarily grow to meet the requirements of a theoretical specification.

It is often said that narrow annual rings, which betoken slow growth, are a sign of strong timber; but this only holds good for wood of the same botanical species grown under the same conditions of soil and climate.

Timber which is woolly under the plane, or which clogs the teeth of the saw in working, is unreliable, while if a musty odour be emitted it is a sign of incipient decay, and a dull, chalky appearance is also a sign of bad timber.

Good timber is an excellent conductor of sound. The ticking of a watch applied at one end of a balk should be distinctly heard if an ear be placed against the other end; while imperfections in timber in position can be detected by positive differences of sound produced by tapping. Perfect parts will strike solid, surface shakes will rattle or "answer" to the slightest touch, and deep shakes will give a hollow sound, while live knots will sound short and crisp, dead knots answering faintly or rattling.

The following analyses of woods are interesting, as showing how slight are the chemical differences :—

—	Carbon.	Hydrogen.	Oxygen.	Nitrogen.
Beech	49·89	6·07	43·11	0·93
Oak	50·64	6·03	42·05	1·28
Birch	50·61	6·23	42·04	1·12
Willow...	50·31	6·32	42·39	0·98
Poplar	51·75	6·19	41·08	0·98
Ash	49·18	6·27	44·55	...
Fir	50·36	5·92	43·67	0·05
Pine	50·31	6·20	43·45	0·04

TIMBERS GENERALLY USED FOR PARTICULAR PURPOSES.

Purpose.	Timber.
General house carpentry—	European Pine and Fir.
Do. where strength and durability are required.	American Pine, Pitch Pine, Oak, Jarrah (rare).
General joinery—	European Pine, American and Canadian Pine, Maple (rare).
Do. where strength and durability are required.	Oak, Pitch Pine, Teak, Mahogany.
Do. where ornamental appearance is required ...	Pitch Pine, Oak, Figurey Teak, Birds-eye Maple, Mahogany, Walnut.
Piles (partially submerged) ..	Greenheart, European Pine, Pitch Pine.
Work entirely under water ...	Greenheart, Elm.
Elasticity	Ash, Small Chestnut, Yew, Lancewood, Hazel.
Elasticity with toughness ...	Oak, Beech, Elm, Lignum Vitæ, Walnut, Hornbeam, Jarrah or Karri.
Even grain (for carving) ...	Pear, Kaurie Pine, Box, Sycamore, Holly.
Durability in dry works ...	Cedar, Oak, Poplar, Yellow Pine, Chestnut.

Timber Marks Employed in Different Countries.

Norwegian	Stencilled in blue paint on ends with shippers' initials.
Swedish	Stencilled in red; inferior qualities in blue.
Russian	Hammer branded with devices on ends.
Prussian	Scribed (letters roughly formed with a gouge) on sides near the middle.
Canadian	Stencilled in black and white.
American (U.S.) ...	Marked with red chalk on sides.
East Indian ...	Dry branded on ends.
West Indian ...	Scribed on end, with shippers' marks and super contents in white paint on sides.

Timber Measures.

Standard	165 c. ft.
„	720 ft. lineal of 11 ins. × 3 ins.
„	60 pieces, 12 ft. × 11 ins. × 3 ins.
Fathom	216 c. ft. (6 ft. × 6 ft. × 6 ft.).
Cord	128 c. ft. (8 ft. × 4 ft. × 4 ft.).
Load (of hewn timber) ...	50 c. ft.
Load (of unhewn timber)	40 c. ft.
Square	100 sq. ft. (10 ft. × 10 ft.).

WEIGHTS AND STRENGTHS.

No.	Name.	Weight per cubic ft. in lbs.	Mean Crushing Weight per sq. in. in direction of fibres in tons.	Force required to Compress the Woods across fibres $\frac{1}{20}$ of an in. per sq. in.
	PINE WOOD.		Tons.	Tons.
1	Cedar	41	2·56	...
2	Fir	40	2·50	0·22
3	Larch	35	2·48	...
4	Pine, Memel	36	2·90	0·60
5	,, Riga...	30	2·30	...
6	,, red, American	36	2·20	...
7	,, pitch	50	2·90	...
8	,, white	28	1·85	0·27
	HARD WOOD.			
9	Alder	35	3·06	...
10	Ash	50	3·50	1·03
11	Beech	51	3·80	...
12	Birch	45	2·72	...
13	Ebony	70	8·40	...
14	Elm	39	2·50 to 3·50	...
15	Jarrah	51	3·20	...
16	Lignum Vitæ	80	4·25	2·5
17	Mahogany, St. Domingo ...	53	3·00	0·58
18	,, Honduras	42	2·80	1·92
19	Maple	47	2·70	0·91
20	Oak, English	50	3·20	0·90
21	,, Dantzic	48	3·20	0·84
22	,, American, white	53	2·97	0·89
23	,, ,, red	47	2·68	...
24	,, ,, live	70	3·54	2·28
25	Sycamore or Plane Tree ...	37	3·20	...
26	Teak	46	3·80	...
27	Walnut	44	3·21	...
28	,, white	58	4·38	1·39
29	,, black	60	2·50	0·71
30	Willow	34	2·73	...

Chapter XXIV.

TIMBER CONVERSION.

At one time, when the timber in general use was either home grown or else imported and purchased by the builder in the form of logs, it was essential for everyone connected with building to understand the principles of timber conversion. Now, however, that most building timber is imported in a ready-converted state, this necessity no longer exists so strongly, save to assist discrimination in selecting ready-converted timber for particular purposes.

The whole matter is admirably explained in Dr. Anderson's "Strength of Materials," written some thirty years ago, and there is little to add to what he then said, further investigation having but proved the correctness of his assertions.

Longitudinally the shrinkage of timber is so slight that it may be disregarded—and generally is disregarded—in practice. The timber in old structures will frequently be found to have sagged and twisted and split, but any diminution in length will be inappreciable. On the other hand, transverse shrinkage is considerable. As already explained, the trunk of a tree consists of a number of roughly concentric rings, each representing a year's growth, yet made up of longitudinal fibres forming cells. The annual rings are held together by a radial structure, known as the "medullary rays" or "silver grain," of a stiff nature, difficult to compress. Thus heart and star shakes are accounted for, by radial splitting parallel to the medullary rays when the wood is called upon to part with its moisture during seasoning, this necessarily resulting in decrease of bulk, while the stout medullary rays resist decrease in diameter.

The annual rings have by no means the same power of resisting collapse, and it is upon their weakness in this respect compared with the strength of the medullary rays that most of the phenomena noticeable during seasoning are due.

Take, for instance, a log which has been cut into four "quarters" by saw-cuts through the heart, two quarters being shown in Figs. 132 and 133. That upon the right-hand side (Fig. 133) is "square," the saw cuts being at right angles to one another. This is its shape when first cut. After the lapse of a few months or a year, however, the appearance will have altered to that shown on the left-hand side (Fig. 132), the size having diminished to the extent of the black wedge-shaped portions. The stiff medullary rays will have retained their length, and the diameter of the timber is the same as before; but the annual rings will have partially collapsed, bringing the medullary rays nearer together and reducing the circumference.

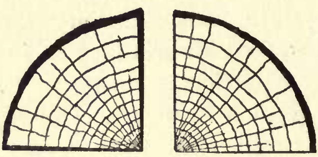


Fig. 132. Fig. 133.

Shrinkage in Quartered Timber.

The same laws govern the shrinkage however the timber is cut. Suppose a series of planks be obtained by means of parallel saw-cuts, as shown in Figs. 134, 135 and 136. The plank illustrated in Fig. 134 contains the heart, and its thickness will be maintained at the centre by the resistance of the medullary rays, and its breadth will also be maintained in the same way; but its thickness will diminish towards the edges, by the collapsing of the annual rings.

An intermediate plank, such as is shown in Fig. 135, will behave differently, although governed by the same laws. The contraction of the annual rings combined with the resistance of the medullary rays will cause it to warp,

becoming convex on the side nearer the heart, and concave on the farther side, which will diminish considerably in width. At the same time the thickness is less affected than is that of the central plank.

Fig. 134. Centre Plank from Log.

In the outer plank (Fig. 136) the warping is still more noticeable, while the reduction of thickness is reduced to a minimum.

Fig. 135. Intermediate Plank from Log.

Thin floor boards are particularly liable to warp in this way, for they are usually cut as shown in Fig. 135, and are nailed with the side which is nearer the heart downwards. Thus the edges are liable to rise and the boards to separate, sharp ridges being formed. There is no reason why they should not be nailed with the convex side upwards where the floors are to be carpeted; but if they are to be left bare this would soon result in pieces kicking up as shown in Fig. 137, and from the fact of this happening has grown up the custom of nailing them with the heart downwards. A little consideration would show, however, that this would not happen where a floor was always kept covered, while sharp ridges are distinctly harmful to an overlying carpet.

Fig. 136. Outer Plank from Log.

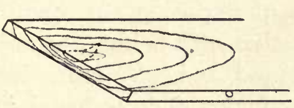


Fig. 137. Effect of Nailing Floor Boards with Heart upwards.

Hard woods, such as oak, teak, etc., show these peculiarities much more markedly than do the soft fir timbers in general use, for they have much more highly developed medullary rays. Such woods, too, are more frequently cut in square sections, and these, obeying the same laws as have been already

explained, have a tendency to alter from the form shown in Fig. 138, to that shown in Fig. 139. This is often

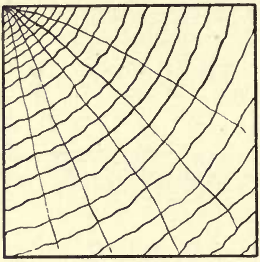


Fig. 138. Squared "Quarter" when newly Cut.

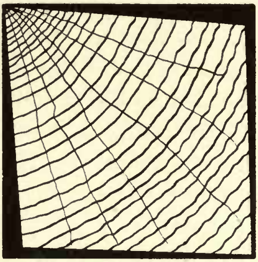


Fig. 139. Squared "Quarter" after Seasoning.

noticeable in oak posts; and perhaps the effect is worst when a circular post has been cut out of such a "quarter," as it soon loses its circular shape and becomes elliptical. A case within the author's experience is one of a circular oak column resting on an oak base, each cut in this way, but set up so as to contract in different directions, with the result that the two circles have become ellipses, with different axes, now that they have been erected for a few years.

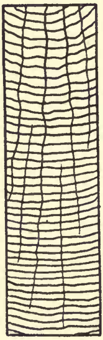


Fig. 140. Hardwood Converted to show Medullary Rays.

Hard woods are, however, not infrequently cut as shown in Fig. 140. This is generally done for the purpose of exposing the medullary rays, for decorative effect, but, beyond this, warping is prevented, as is also reduction of width, though the thickness is reduced, in the process of seasoning. Another advantage is also secured, inasmuch as experiment shows that timber cut in this way has greater strength, when employed as a beam, than if otherwise cut; and this is to be expected from the fact of the stiff medullary rays occupying a vertical, or nearly vertical, position in

the beam, while the stronger annual rings which occur near the heart are kept in compression, and the weaker outer rings in tension.

In the conversion of oak and other ornamental hard woods, the method to be pursued would vary according to the purposes for which the timber was to be used. If it be wanted for ornament mainly, the logs would be cut so as to show the peculiar grain or figure of the wood to the best advantage. Thus, after the log has been "quartered" (divided into four quarters by cuts passing through and

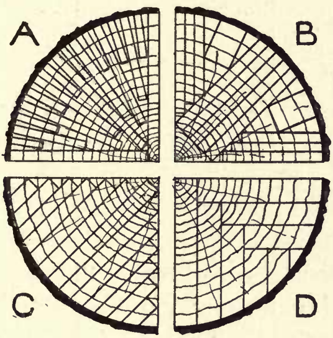


Fig. 141.

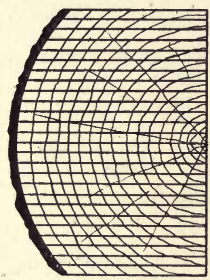


Fig. 142.

exposing the heart), either of the methods, A, B or C, shown in Fig. 141, could be used to display the silver grain of oak, while the method shown of converting the fourth quarter, D, might be used for the production of thick stuff for constructional purposes. Oak logs cut through the heart, and then with the corners removed as in Fig. 142, are known as "WAINSCOT," from which wainscot boards are obtainable, as shown in the illustration.

On the other hand, the soft pine timbers are generally converted with little regard to anything save obtaining the greatest possible number of marketable sizes out of a given log. An effort is, however, made to expose the heart, at any rate in the larger scantlings and higher grades of timber, four deals being generally obtained from each log,

as shown in Fig. 143, though a thin board including the heart ought to be entirely removed.

The following table gives the scantlings usually cut from trees of given diameters at the White Sea ports, and it will be admitted that the most is made of the wood available, especially in the smaller sizes :—

Diameter of log ...	ins. $12\frac{1}{4}$	ins. $13\frac{1}{8}$	ins. 14	ins. $14\frac{7}{8}$	Larger
Two inner deals or planks	9×3	11×3	11×3	11×3	ins. 11×3
Two outer deals or planks	$9 \times 1\frac{1}{2}$	$11 \times 1\frac{1}{4}$	$11 \times 1\frac{1}{2}$	$11 \times 2\frac{1}{2}$	11×3

Of these, the outer deals necessarily consist almost entirely of sapwood, and are liable to warp ; besides which there is considerable likelihood of their running out beyond the bark in places, if not throughout their entire length, and so presenting what are known as "waney edges" (see Fig. 144). In fact, only the inner deals from the larger trees consist entirely, or almost entirely, of heartwood, and so these alone are suitable for high-class work.

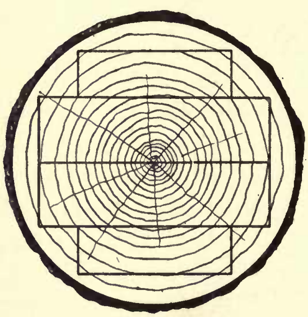


Fig. 143.

Fig. 144.

Unfortunately there is a great demand for quite small scantlings of immature and inferior timber. It consequently pays best to cut European fir long before it has reached the sizes mentioned, very small

stuff being cut from very young trees consisting almost entirely of sapwood.

There is much confusion in the use of terms to denote the various market forms of timber, but the following definitions are now pretty generally accepted :—

Log	The trunk of a tree with the branches lopped off.
Balk (or squared timber).	A roughly squared log.
Inch masts ...	Long, straight, sound logs, dressed to a square or octagonal shape, and more than 72 ins. circumference at base.
Hand masts ...	Long, straight, sound logs, dressed to a square or octagonal shape, between 24 and 72 ins. circumference at base.
Spars or Poles ...	Long, straight, sound logs, dressed to a square or octagonal shape, under 24 ins. circumference at base.
Planks	Rectangularly cut pieces of timber 11 ins. wide (or more).
Deals	Rectangularly cut pieces of timber 9 ins. wide (or more).
Battens	Rectangularly cut pieces of timber 7 or 5 ins. wide (or more).
Boards	Thin pieces of timber of any width.
Ends	Short pieces of timber of any scantling.

It may be remarked, however, that the terms LOG and PLANK are by timber merchants now reserved for hardwoods and for American white-wood, all imported sawn converted timber, cut from pines or firs, being classed as BALKS, DEALS, BATTENS, and BOARDS; or, if planed, as PLANED JOINERY BOARDS, FLOORING, or MATCHED BOARDS. The term DEAL is thus made to include all sizes between 11 ins. by 4 ins. and 7 ins. by $2\frac{1}{2}$ ins.

There is a distinct difference between both the width and the thickness of ready-prepared timber as ordered and as supplied—by the amount of wood removed by the planing machine; and in tongued boarding the width of the tongue also has to be accounted for. This is a trade custom, and has to be accepted, though it would be easy to make the necessary allowances before conversion, and so supply exactly what was ordered. The following table shows the

loss, and also, in another column, tells us how many feet run of the nominal size are sold as a "square," while as a rule a much larger quantity is actually needed to cover a "square" of 100 ft. super :—

FLOORING, MATCHING, ETC.

Trade Size.		Actual Sizes.			
Width so-called.	No. of Running Feet sold as a Square.	Actual Width Straight Joint.	No. of Running Feet in a Square.	Ploughed and Tongued: holds this Width only.	No. of Running Feet in a Square.
ins.	ft.	ins.	ft.	ins.	ft.
9	140	$8\frac{11}{16}$	139	$8\frac{1}{2}$	142
8	160	$7\frac{11}{16}$	157	$7\frac{1}{2}$	160
$7\frac{1}{2}$	170	$7\frac{3}{16}$	167	7	172
7	180	$6\frac{11}{16}$	180	$6\frac{1}{2}$	185
$6\frac{3}{4}$	185	$6\frac{7}{16}$	188	$6\frac{1}{4}$	192
$6\frac{1}{2}$	190	$6\frac{3}{16}$	194	6	200
$6\frac{1}{4}$	195	$5\frac{15}{16}$	203	$5\frac{3}{4}$	209
6	200	$5\frac{11}{16}$	211	$5\frac{1}{2}$	219
$5\frac{3}{4}$	210	$5\frac{7}{16}$	221	$5\frac{1}{4}$	229
$5\frac{1}{2}$	220	$5\frac{3}{16}$	232	5	240
$5\frac{1}{4}$	230	$4\frac{15}{16}$	245	$4\frac{3}{4}$	253
5	240	$4\frac{11}{16}$	256	$4\frac{1}{2}$	267
$4\frac{1}{2}$	270	$4\frac{3}{16}$	287	4	300
4	300	$3\frac{11}{16}$	326	$3\frac{1}{2}$	344
$3\frac{1}{2}$	350	$3\frac{3}{16}$	377	3	400
3	400	$2\frac{11}{16}$	447	$2\frac{1}{2}$	480

It is also necessary to remember that in the thickness of boards $1\frac{1}{4}$ in. flooring or matching finishes $1\frac{1}{16}$ in., 1 in.—$\frac{7}{8}$ in., $\frac{7}{8}$ in.—$\frac{11}{16}$ in., $\frac{3}{4}$ in.—$\frac{9}{16}$ in, $\frac{5}{8}$ in.—$\frac{7}{16}$ in., $\frac{1}{2}$ in—$\frac{5}{16}$ in.

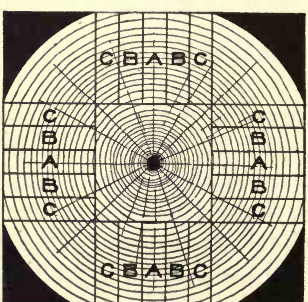


Fig. 145.

Floor boarding ought to be cut as shown in Fig. 145, the boards A, B, and C being properly cut, and all the rest of the log removed for other purposes. That is, the boards should as nearly as possible be cut radially from the centre of the log.

Many of the more beautifully figured hard woods—and

sometimes the soft woods also, especially figured pitch-pine —are also cut into extremely thin slices, called VENEERS, which are carefully glued upon the face of straight-grained wood and then polished. Owing to their thinness, these veneers can be bent round most mouldings, and the effect produced is the same as if the more expensive wood had been used entirely; which as a rule would not be possible, for the twisted grain of the highly ornamental woods renders them so liable to warp and twist as to make their use out of the question unless they are backed by straight-grained wood.

It may be noted that if one side of thin wood be veneered the other side should be veneered also, else bending will surely result.

Not many years ago all timber was imported in log and sawn in a saw-pit, such as is still to be found in some parts of rural England. Two men were employed, one working in the pit below the timber, and the other above it, each holding one handle of a long two-handled saw. Lines were first marked on the log, and these had to be followed by the sawyers, else twisted planks of unequal thickness were the result.

At the present time power—sometimes steam and sometimes electricity—is always used to drive the saw; and it is the timber which travels to the saw, and not the saw to the timber. For single cuts, a circular saw is used, accurate thickness being obtained by keeping the timber against guides as it reaches the saw, which works with great rapidity. If the timber be wanted for flooring, match-boarding, or mouldings, it goes on to other machines, which plane its faces, and, if necessary, plough any grooves or cut any mouldings, at a speed utterly unapproachable by hand.

Hard-wood or pitch-pine logs of any considerable size are, however, often dealt with by a saw having several vertically reciprocating blades set at the desired distances apart, all of which work simultaneously; and although the rate of travel is not so great as it is to the circular saw, this

is more than compensated for by the number of blades employed. These reciprocating saws, being but a development of the vertical hand saw, require a pit to drop into—often a basement beneath the sawing floor—which serves for the collection of sawdust.

Attention cannot be too strongly drawn to the fact that, owing to the small size of the timber felled, and to the method of conversion adopted, scarcely any fir timber is procurable "free from sap." The phrase is used in most architects' specifications, but has been held at law to mean "reasonably free from sap," and this permits the use of timber of which as much as 50 per cent. may be sapwood. If timber is really required to be free from sap, it must be specified as "absolutely" free from it, and to obtain such timber the imported wood must generally be cut down in an English saw-mill and the sapwood sacrificed, at considerable cost.

Chapter XXV.

TIMBER SEASONING AND PRESERVATION.

TIMBER produced from a newly-felled tree, whether it be heartwood or sapwood, is full of sap, and if this is not properly extracted by drying or seasoning the wood will shrink, warp, and shake after it has been placed in position.

The most obvious effect of seasoning is the reduction of weight, which varies with different timbers, and is carried to a different extent according to the purpose for which the timber is required. The following table must accordingly be accepted as approximate only, the degree of seasoning which is sufficient for carpenters' work and common purposes being by no means satisfactory for framed work and high-class joinery :—

LOSS IN SEASONING BY WEIGHT.

Red pine	12 to 25	per cent.
American yellow pine ...	18 to 27	"
Larch	18 to 27	"
British oak	16 to 30	"
Elm	about 40	"
Mahogany	16 to 25	"

Logs ought to undergo considerable preliminary seasoning before being cut into scantlings, but as pine and fir timbers are not imported in logs, no control over this can be exercised in England in their case. Home-grown timber, however, such as oak, elm, and beech, and imported hard woods as well as American white-wood, which arrive here in logs, should be, and practically always are, thus treated. The NATURAL PROCESS is generally used, but WATER SEASONING is occasionally preferred. For instance, it is stated that

"Elm felled ever so green, required for sudden use, if plunged four or five days in water (especially salt water) obtains an admirable seasoning, and may be immediately used, but owing to its great shrinkage is only suitable for purposes where it will be entirely submerged."

After conversion the scantlings should be further seasoned, and as a general rule it is at this stage that the principal seasoning is performed, generally by the NATURAL PROCESS,

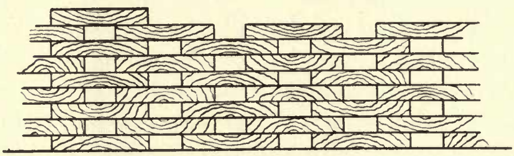


Fig. 146. Stacked Timber.

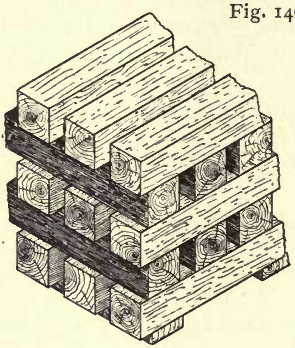


Fig. 147. Seasoning Balks.

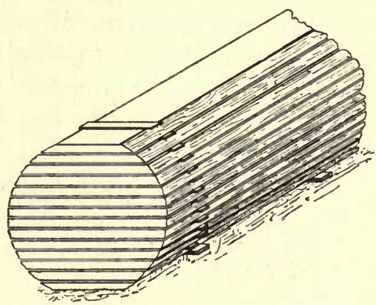


Fig. 148. Seasoning Boards.

but frequently by one or other of the several artificial processes known, of which some will be described, though new ones are being constantly introduced, being usually dropped again after a short trial, either on the score of expense or of inefficiency.

Still further seasoning is necessary for good joinery work after it has been planed and lightly wedged together, that the final shrinkage may take place before firmly wedging and gluing; while floor boards should, if possible, only be tacked down for some months, and then taken up, clamped tightly together, and firmly nailed.

However well seasoned timber may be, it will certainly warp and twist if introduced into an unfinished, damp house.

NATURAL SEASONING.

Natural seasoning is carried out by merely stacking the timber, preferably under cover, so as to protect it from rain, wind, and sun, in such a manner that air can circulate freely round each piece. The stacking ground should be paved, or at any rate dry, covered with ashes, and free from vegetation, and the lower tiers of timber should be raised from it on carefully levelled bearers, to prevent the timber from acquiring a permanent twist. Exposure to fierce sun-heat is also particularly to be avoided, as it causes fine cracks to open.

There are several methods of stacking, some of which are shown in Figs. 146, 147, and 148; while boards are also frequently stacked vertically or nearly so, and logs are generally stacked with the butts outwards, the inner ends being slightly raised and packing pieces inserted, so that any particular log may be withdrawn without disturbing the whole stack.

The time required for natural seasoning is considerable, and varies according to the nature of the wood, the size of the pieces, and its condition before seasoning, while it takes nearly half as long again in the open as it does under a sheltering roof. Laslett says: "My experience of the approximate time required for seasoning timber under cover and protected from wind and weather, is as follows :—

	Fir. Months.	Oak. Months.
"Piles 24 ins. and upwards square require about ...	26	13
,, under 24 ins. to 20 ins. square	22	11
,, ,, 20 ,, 16 ,, ,, ...	18	9
,, ,, 16 ,, 12 ,, ,, ...	14	7
,, ,, 12 ,, 8 ,, ,, ...	10	5
,, ,, 8 ,, 4 ,, ,, ...	6	3

"Planks from $\frac{1}{2}$ to $\frac{2}{3}$ the above time, according to thickness."

If proper precautions be taken against warping and splitting, no process of seasoning is superior to this.

WATER SEASONING.

Water seasoning is frequently used where there are handy ponds or pools of running water, especially for log timber before conversion, in order to hasten the subsequent processes.

It consists in chaining the timber under water, preferably as soon as it is cut, but more often after its arrival in England from the country of its growth, and leaving it thus, with the butt end up stream, for a fortnight or longer (often for several months if it is not required sooner for use), that the sap may be washed out. For this to be effectual, the timber should be entirely immersed, though frequently the wood is merely allowed to float in stagnant water, injuring it along the water line, and merely soaking the submerged portion, without there being any movement to assist removal of the sap, while stagnant water is also frequently discoloured, and stains result.

When properly done the process of seasoning is materially hastened, careful drying in the open air following the water seasoning; but while it is rendered less liable to warp and crack owing to the lesser period of air seasoning, its strength and elasticity are said to be impaired. This is less noticeable if salt water be used, as it frequently is in harbours; but for building works salt-water seasoned timber is scarcely admissible, on account of its liability to attract moisture.

Timber which, in its country of origin, has been floated to the coast, may be said to have been partially water-seasoned before importation. Such timber, like all other which is water-seasoned, must be thoroughly dried before use, else it will be exceedingly liable to dry rot.

Water seasoning can be quickened by using boiling water or steam, but this is rarely done, as it is expensive and tends to reduce the strength and elasticity of the timber. Steaming is, however, employed for the purpose of enabling timber to be bent to any particular shape, and as it effects the seasoning at the same time, nothing more than careful drying is afterwards required to fit it for immediate use. About an hour's exposure to steam is necessary for every inch of thickness.

HOT-AIR SEASONING (DESICCATION).

A considerable amount of timber, especially pitch-pine from the Southern States of America, is "stoved" before it

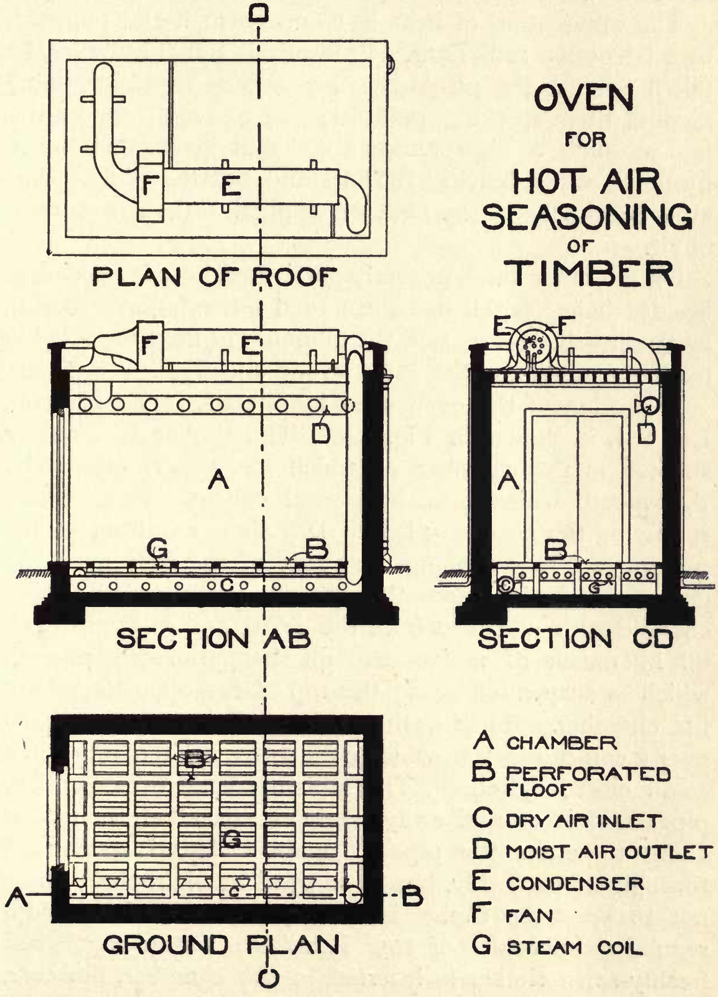


Fig. 149.

is imported into England. This may not be very scientifically done, but it is so far effectual that it prevents the sapwood from turning blue, and renders it extremely difficult to detect the difference between sapwood and heartwood.

The application of heat is of no harm if the temperature be under 120° Fahr. Precautions must, however, be taken against the pieces twisting, and in rapid seasoning against their cracking radially; and above all in seasoning at such a high temperature that strength is taken from the wood, leaving it short and brittle. This occurs most markedly if the heat be applied without a current of air.

On the other hand, properly performed, hot-air seasoning, besides being rapid, has the added advantage of driving away all valueless matter, the albumen in the timber being made insoluble and the fibres strong and rigid.

A section of the oven used by Messrs. James Latham, Limited, is shown in Fig. 149. The timber is carefully stacked in the chamber A, which has a perforated floor B, beneath which is a horizontal coil of steam pipes, supplying the necessary heat. Dry air is admitted by the perforated pipe C along one side of the bottom of the chamber. As it passes through the chamber it becomes charged with moisture from the wood, and is then drawn off by means of a fan through the perforated pipe D, which is suspended along the top of the opposite side of the chamber. Thence the moisture-laden air is driven over a coil of pipes in which cold water is circulating, in a small closed cylinder. The moisture condenses on these pipes and is carried away, while the dried air is passed along to enter the pipe C again. This is continued throughout each day, but is stopped at night-time, so as not to keep the timber constantly under tension; and a regular temperature of 105° Fahr. is maintained. When freshly-sawn timber is inserted in the chamber, however, open steam instead of dried air is admitted into the chamber

for the first few hours, in order to dissolve the sap and make it more easy to deal with.

Freshly-cut oak, one inch thick, takes between three weeks and a month to season by this process, which is hardly applicable to large scantlings, while the length is limited by that of the chamber. If the rate of seasoning be forced, either by quickening the flow of air or raising the temperature, or by keeping it going constantly night and day, the result is not satisfactory, a hard and brittle surface being produced.

It may be pointed out here that stoved or desiccated wood is liable to reabsorb moisture from the air and return to its original unseasoned condition. If used for joinery, it should consequently be kept in a warm drying room between the times of being worked up and being finally fixed, and should be painted (primed) before fixing, preferably before leaving the drying room, and certainly before insertion in an unfinished, and consequently damp, house.

McNEILL'S PROCESS.

Exposure to the products of combustion of a fire, in a chamber which contains a large surface of water, this being known as McNEILL'S PROCESS, is in principle much the same as desiccation, the result being to make damp, warm air circulate amongst the timber. Efficiently performed, it is equally good, and it is somewhat largely used. It is said that this process renders timber harder, denser and tougher, while entirely preventing dry rot, and that it is best to treat the wood in as green a state as possible. If the heat applied be not too great, sound timber will neither split or warp in the slightest degree, and at the same time thorough seasoning takes place; while subsequent exposure to the atmosphere will not result in any material absorption of moisture—at any rate to not the same extent as happens after dry air seasoning.

SMOKE-DRYING.

Occasionally the seasoning of timber is hastened by drying it over a bonfire of straw, shavings or furze. This is said to render it proof against the attacks of worms, and to make it hard and durable; but the process is rough and somewhat elementary, and is likely to lead to the timber splitting if the heat is not applied very gradually so as to dry out the moisture from the interior.

PRESERVATION BY PAINTING, OILING, TARRING, OR CHARRING.

The best seasoned timber will not stand exposure to weather in England for more than 25 years unless some further means be taken to preserve it, and although oak in a dry and well ventilated position has been known to last a thousand years, it is customary to paint all exposed timber in ordinary building works.

The effect of painting is merely to cover the surface with a thin film which is impervious to moisture, but as paint is itself perishable, it needs to be renewed, generally once every three years if exposed to the weather. This preserves timber for a very long period, *provided that it has first been thoroughly seasoned.* This is a very important point, for otherwise the filling up of the outer pores only confines the sap, and so leads to decay. In such a case, it is usually the sapwood which decays first, but properly seasoned timber, whether it be sapwood or heartwood, seems to be equally well preserved by painting.

Oiling and tarring have precisely the same effect as painting, save that tar is less perishable than paint and rarely needs renewal, except where it is exposed to sun-heat. Tarring is consequently much used for timber which is inserted in the ground or placed close to the ground and out of sight, and for hidden ends and bedded surfaces of timber in constructional work; but its rough and unfinished

appearance, its stickiness when exposed to heat, and its inflammability render tar unsuited to many positions.

Charring also may be classed with painting and tarring, it being applied to the surface of timber where it enters the ground, with the object of closing the external pores—in this instance permanently.

CREOSOTING.

Many processes for preserving timber by impregnating it with various substances have been put forward from time to time, but the only one which has proved to be practically and commercially successful is that known as CREOSOTING.

Commercial creosote is a dark brown, thickish liquid obtained from coal-tar, of which it constitutes from 20 to 30 per cent. It consists of the light and heavy oils of tar, and is produced from coal-tar by distillation, at temperatures ranging from 350° Fahr. up to 760° Fahr. Its composition is very variable, and but little appears to have yet been accomplished in the way of fixing any standard of purity, or of recording the complexity of its many constituents.

The timber to be treated should be thoroughly well seasoned, and then artificially dried for twenty-four hours. It is then piled in a cylinder, which is closed airtight, and pumped to a vacuum. Creosote at a temperature of 120° Fahr. is now allowed to enter, and after the cylinder is full pumping is resorted to at a pressure of 120 lbs. per square inch. The creosote should be such as to be entirely liquid at 120° Fahr., should contain not less than 25 per cent. of constituents which do not distil over at 600° Fahr., and should yield to a solution of caustic soda not less than 6 per cent. by volume of tar acids, while the specific gravity at 90° Fahr. should lie between 1·040 and 1·065, water being 1·00 at the same temperature.

The process is exceedingly efficacious for soft woods,

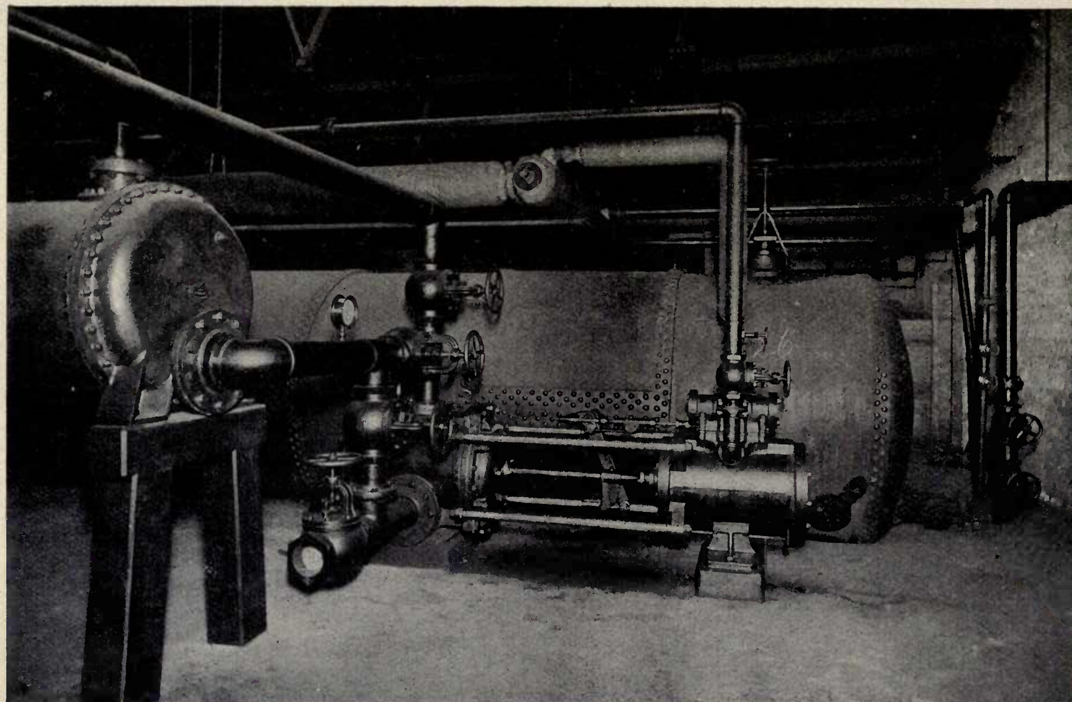
and is invaluable where these are employed for fencing, piles, railway sleepers, or the paving of carriage-ways; but the discoloration produced and the strong odour of the creosote make it unsuitable for use in ordinary building work. Sapwood in particular is improved by creosoting; but there are several of the hard woods, including pitch-pine, which the liquid cannot penetrate.

An imperial gallon of creosote weighs about 10½ lbs. The amount usually absorbed by timber is from 8 lbs. to 13 lbs. per cubic foot; but dry beech has been known to absorb as much as 24 lbs. per cubic foot.

NON-FLAMMABLE WOOD.

Many processes have been put forward for the preservation of timber from fire, with little success till recently. One, the chemicals employed in which are not revealed, which is now used by the Fire Resisting Corporation, Limited, has of late years proved successful, and not only renders the wood highly fire resisting, but has the further advantages of seasoning and drying it at the same time—within a month of its being felled if necessary—while the chemicals used are antiseptic, odourless and harmless, and do not injure the wood. The following descriptions are taken from the company's pamphlet:—

"The timber to be treated is stacked on low wheel trollies running on tracks laid from the stacking yard into the treating retorts or cylinders, which are 105 ft. in length and 7 ft. in diameter (see photographic illustration). The loaded trucks are then run into the treating cylinder, more or less trucks being employed according to the quantity of timber to be treated, and the door of the cylinder closed. The load is now subjected to changes of temperature and certain manipulation, by which means the volatile and fermentable constituents of the wood are withdrawn and the pores of the wood prepared for the reception of the fireproofing ingredients. When the timber is ready, the



The Fire-Resisting Corporation's Impregnating Cylinders for Non-Flammable Wood.

latter is presented to it in the form of a solution of a certain definite strength, such strength varying with the description of wood under treatment. Hydraulic pressure is next applied until the wood is thoroughly saturated. The cylinder is then opened and the load withdrawn, which, if the cylinder be full, will consist of 20,000 cubic feet.

"The wood, now thoroughly saturated, and, consequently, more than double its original weight, is re-stacked and run into the drying kiln, which is a large room fitted with heating apparatus, and air fans to circulate warm currents of air, and condensing apparatus to condense the vapour arising from the wood. In about thirty days a load of wood of average thickness should be dry; that is, the aqueous portion of the solution has been drawn off, leaving the fireproofing ingredients closely incorporated with the cellulose in the pores of the wood.

"The wood is now ready for delivery, and, owing to the fact that the volatile and fermentable constituents have been driven off and their place filled with antiseptic material, no rot can take place. Besides, as the wood has been equably dried, the possibility of after-warping is avoided; and since the interstices of the wood are packed with material, no after-shrinkage is possible."

Some woods lend themselves more advantageously than others to the process—notably the open-grained non-resinous woods; while those woods that contain large quantities of pitch and resin, such as pitch-pine, and woods that are very oily in their constituents, such as teak, prove to be sometimes more or less refractory to the treatment. Woods of this class after treatment, while liable under conditions of very intense heat to inflame, are, nevertheless, most difficult to ignite, and consequently afford a protection against fire far greater than if the wood was untreated. In the case, however, of non-resinous and non-oily woods, where complete impregnation can be effected, the treated wood is said to effectually and permanently resist the spreading of flame.

Chapter XXVI.

TIMBER CLASSIFICATION : SOFT WOODS.—NOTES FOR USERS.

ALL building timber may be broadly classed under two heads, SOFT WOODS and HARD WOODS ; the terms *soft* and *hard*, however, being used in a very general sense, some of the so-called *soft woods* being harder than some of the *hard woods.* This comes about through the term *soft wood* being applied, as a popular name, to all timber of the natural order of *Coniferæ*—that is, to all timbers which in their growing state are cone bearing, and have spikes instead of leaves—all others being known as *hard woods.*

The following classification of timber, which is a modification by Professor Rankine and Mr. Hurst of that originally proposed by Tredgold, is now generally accepted :—

CLASS I.—SOFT WOOD or PINE WOOD (resinous and coniferous), having very distinct annual rings, one part of each ring being hard and dark and the other soft and light coloured, while the pores are filled with resinous matter. Pine, Fir, Larch, Cowrie, Cedar, Cypress, Yew, and Juniper all belong to this class.

CLASS II.—HARD WOOD or LEAF WOOD (non-resinous and non-coniferous), the various examples of which may be subdivided as on page 247.

When more detailed classification is attempted, however, the confusion which exists in nomenclature introduces an element of extreme difficulty, which is accentuated by the fact that, in the ready-converted form, it is often almost impossible to distinguish between even botanically different timbers, to say nothing of botanically similar timbers sold commercially under different names and

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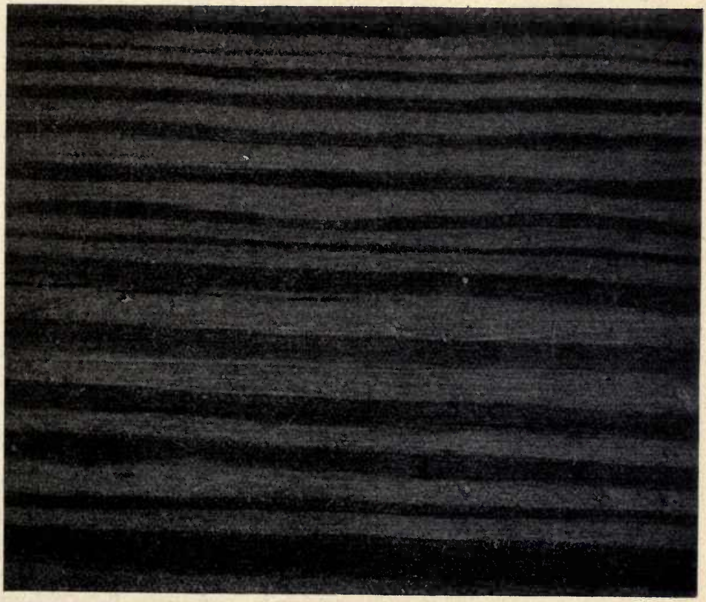

PITCH-PINE.

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shipped from different ports. This is especially the case amongst the soft woods, which are almost exclusively used for ordinary building work—to such an extent that the great forests of Northern Europe have been nearly denuded of well-grown timber, so that large balks, free from sap-wood, are hardly obtainable; which is scarcely surprising, considering that a well-grown pine tree takes from 180 to 300 years to reach maturity, according to climate, and that the slower-grown timber is generally the best.

	DIVISION I. With distinct large medullary rays.	DIVISION II. Without distinct or large medullary rays.
Sub-division I. With distinct annual rings, one side porous and the other compact.	Oak.	Ash, Elm, Chestnut.
Sub-division II. Annual rings not distinct, and the texture nearly uniform.	Alder, Beech, Plane, Sycamore.	Greenheart, Mahogany, Poplar, Teak, Walnut.

The two following trees, whose ages were computed by the number of annual rings, may be compared :—

The first, grown 680 miles north of London—$24\frac{1}{2}$ ins. diameter at 5 ft. above ground ; 85 ft. high ; 216 years old. The second, grown 1,160 miles north of London—$23\frac{3}{8}$ ins. diameter at 5 ft. above ground ; 59 ft. high ; 365 years old.

Of these the first showed the less heartwood, and a balk 14 ins. square was obtainable from it of heartwood only; while from the second, a similar heartwood balk was only obtainable $12\frac{1}{2}$ ins. square.

An attempt to remove confusion has been made in the following tables, but the descriptions are necessarily inadequate, and students are recommended to trust more to

experience gained by personal inspection than to anything they may read. It may also be pointed out that the characteristics mentioned as applicable to the timber from any port are due not to any peculiarities of the port, but to the climate and soil of the district where the timber has been grown—possibly hundreds of miles distant

The following pseudonyms for the general classes of soft woods may be here noticed :—

Botanical Name.		Popular Pseudonym.
Abies	... ...	Fir
Larix	... ...	Larch
Picea	... ...	Spruce
Pinus	... ...	Pine
Tsuga	... ...	Hemlock

North America is much more rich in varieties of fir timber fit for building purposes than is Europe, and as a general rule the American timber now imported is superior to the European, although the effect of reckless felling is being felt, and large sound timber is not always easy to obtain. Much of the American wood is, in its converted form, almost indistinguishable from the European, however, save by the system of branding and the marks adopted; so that one is frequently substituted for the other. As a general rule, London and the eastern coast of England are supplied from the Baltic, while Liverpool and the western coast are supplied from America.

On account of confused nomenclature it is again desirable to adopt a tabular system of classification, the same timber being frequently known by several names, and, at least in the case of pitch-pine, several different timbers being known by the same name. In each case the first name given will be that in most common use in England.

EUROPEAN SOFT WOODS.

Botanical Name.	Popular Pseudonyms.	General Characteristics.	Country where Grown.	Port whence Shipped.	Special Characteristics and Uses.
Pinus Sylvestris	Baltic Fir, Baltic Pine, Northern Pine, Scotch Fir, Red Deal or Yellow Deal	A clean, straight-grained wood, easy to work, and moderately free from knots. Moderately strong, tough and durable when free from sapwood. The most commonly used timber in building works.	Prussia	Dantzic Memel	Formerly sound wood of good length and scantling. Not many large trees left. Still excellent timber if obtainable free from sapwood. Suitable for good carpentry.
			Russia	Baltic Ports: Danztic, Memel, Riga, Libau	As above.
				Gulfs of Bothnia and Finland: St. Petersburg, Uleaborg, Vyborg, Abo, Reval, Helsingfors	Even the first quality cut with much sap-wood, often with the heart contained and sometimes shaky, while small scantlings are commonly all sapwood. The lower qualities are mere rubbish.
				White Sea: Archange, Onega, Kem	Often as above, but some good wood for joinery purposes.
			Sweden	Hafaranda Niederkalix Lulea Gefle	As above, but good wood for flooring.
			Norway	...	No timber of any value.
Picea Excelsa.	Spruce, Norway Fir, White Deal	Clean, silky, soft wood, often with many knots.	All above countries	All above ports	Suitable for lower-class flooring, shelving, etc. Very easy to work. That from Russia makes good panels.

Brand marks, it may be said, except as denoting port of shipment, are of little use. They are constantly altering, and the classification in qualities is not always that which is best for building purposes.

AMERICAN SOFT WOODS.

Botanical Names.	Popular Pseudonyms.	Where Grown.	Where Shipped.	Characteristics.	Uses.
Pinus Resinosa, Pinus Rubra	Canadian Red Pine, Red Pine, Norway Pine (Note this curious mistake), Hard Pine	Newfoundland; along N. shores of the Gulf of St. Lawrence; in a belt across Canada to Northern Ontario and South Manitoba	All Canadian and Newfoundland Ports	A clean sound timber, with distinct annual rings and reddish colour. In "culling" or sorting square timber "M" is merchantable timber, the letter being stamped in the end of the log; "U" sound and merchantable, but under merchantable size; "S" second quality; "T" third quality; and "R" rejected and unmerchantable. Deals if merchantable are marked "I"; if second quality "II"; if third quality "III"; and if "culls" X. Obtainable up to 30 ft. long, 12 ins. by 12 ins.	For all general building purposes.
Pinus Strobus, Pinus Tenuifolia	Yellow Pine, White Pine, Weymouth Pine, Soft Pine, Northern Pine, Spruce Pine	Extends from Newfoundland, its northern limit being 57° N. lat., all over Canada and the United States as far south as N. Georgia	All Western Ports of Canada & the United States, particularly from the region of the Great Lakes (Wisconsin, Michigan and Minnesota)	A soft wood, with transition from spring to summer wood in the annual rings so gradual as to be scarcely perceptible, and with fine hair-like black lines, about ¼ in. long, showing along the grain. It is light, stiff and durable, while the resin ducts are small and few, making it easy to work. Obtainable in great width, free from knots, up to 18 ft. long, 1 to 4 ins. thick.	The most valuable timber for internal joinery which is to be painted. Used for all purposes where it grows.
Picea Alba	White Spruce	Canada	Quebec, St. John's, Dalhousie, and Pentecost	Close and straight grained, but not strong. Surface is satiny. Contains small hard knots. Difficult to distinguish between heart and sap wood.	Flooring.
Picea Nigra	Black Spruce	Do.	Do.	Almost identical with White Spruce	Flooring.

Larix Americana, and many other names	Tamarac, Hacmatac, and many other names	Canada and the United States	...	Rare in England	
Pseudotsuga Taxifolia, Pseudotsuga Douglasii (a false hemlock)	Oregon Pine, Red Fir, Douglas Fir	The whole of the United States west of the Rocky Mountains	San Francisco	In two colours, the red being coarse-grained, hard and strong, while the yellow is finer grained and more easily worked. The sapwood is nearly white. As it seasons it becomes hard to work and flinty.	For carpentry and heavy work with little labour on it.
Sequoia Gigantia, Sequoia Sempervirens	Sequoia	West of the Sierra Nevada Mountains in California, from Sacramento on the N. to Deer Creek on the S., in valleys and dark hollows	San Francisco	Soft, weak, brittle and coarse grained; very light in weight (only 18 lbs. per cub. ft.), but durable in contact with damp or soil. The sapwood is narrow and white, and the heartwood a clear red, which darkens in the light to a deeper tone than pencil cedar. It is very straight grained, and the largest timber known, growing up to 400 ft. high and 40 ft. diameter.	Not a good building timber, but takes a high French polish, or a dull polish with white beeswax dissolved in turps.
Pinus Palustris, Pinus Lutea, Pinus Australis, Pinus Serotina, Pinus Palmiensis, Pinus Palmieri	Pitch Pine, Long-leaf Pine, Southern Pine, Turpentine Pine, Rosemary Pine, Brown Pine, Hard Pine, Georgia Pine, Flat Pine, Florida Pine, Texas Yellow Pine and many other names	From N. Carolina to Texas in the United States	Mobile, Sapelo, Pensacola, and Pascagoula, in the Gulf of Mexico	A highly resinous, tough, and clean wood, difficult to work, but obtainable up to 30 ft. in length, and of large scantling of a beautiful grain, sometimes richly marked and curly. Very durable and with distinct annual rings. Should be specified by quality and not by port, as sound, close-grained timber, free from large and dead knots and sapwood	A most useful wood for tie beams and other large structural work. Also for joinery which is to be stained and varnished, and the curly specimens for veneers.

There are three other botanically different timbers, each with several botanical names, and even more popular pseudonyms, which are hardly distinguishable from the true pitch-pine (*Pinus Palustris*) in the converted form, and all of them generally tapped for turpentine before being felled, If there is any difference between them, it lies in the spacing of the annual rings, of which—

True (long-leafed) Pitch-pine	has from	20 to 25	per inch.
Loblolly Pine...	„	3 to 12	„
Cuban Pine	„	10 to 20	„

Short-leafed Pine has not less than 4—usually from 10 to 15 per inch.

The Loblolly pine, of which from one-half to two-thirds is sapwood, is now imported as North Carolina pine, mostly for floor boards, for which it is admirable, being straight of grain, and obtainable up to 20 ft. in length, absolutely free from knots; but it is somewhat hard to work, being, like all other varieties of pitch-pine, exceedingly full of resin.

The only other soft wood calling for notice here is the New Zealand Kaurie pine (*Dammara Australis*). It is a soft, clean wood, straight in grain, and somewhat like the Canadian *Pinus Strobus* in working and uses, being large and free from knots, and consequently suitable for joinery; but the forests have been somewhat wantonly cut, and the timber cannot be replaced, as it is exceedingly slow growing. It shrinks very little after seasoning, and takes a polish.

The extreme confusion which exists in the naming of all soft woods has led to the suggestion of the adoption of the following specification, in which the botanical instead of the popular names are used. If beyond the comprehension of a few, it is not more so than in the existing uncertain naming, while it has the merit of being at least exact.

SPECIFICATION FOR SOFT WOODS.

Ordinary carpenter's work to be of *Pinus Sylvestris*, from Memel, Libau, Dantzig, or Riga ; or of *Pinus Rigida*, from the Gulf of Mexico.

Heavy carpenter's work to be of *Pseudotsuga Douglasii*, from British Columbia.

Best floors to be of mid-Swedish *Pinus Sylvestris*, and other floors of Russian or North Finnish *Picea Excelsa*.

Joinery where exposed to weather to be of *Pinus Sylvestris*, from the White Sea.

Other joinery to be of Canadian *Pinus Resinosa* or Russian *Pinus Sylvestris*, with panels of either Canadian *Pinus Strobus* or Russian *Picea Excelsa*.

All is to be completely free from sapwood, pith, loose or dead knots, and twisted grain, and is to be sawn die square.

NOTES FOR USERS.

Soft timber, having straight grain with slight cohesion between the fibres, should be used in straight pieces.

Allowance should always be made for shrinkage ; panels, for instance, being allowed freedom of movement to prevent splitting.

Joiner's work should be made and lightly put together long before it is wanted, being only finally glued up after the initial shrinkage has taken place.

In constructional work, timber may be used under direct compression, tension, or transverse stress ; but it is not suited to resist shearing along the grain. Where this is unavoidable the joints must be very carefully made.

Mouldings should not be undercut, nor should there be any other than simple carving in soft woods.

All timber must be kept dry and well ventilated, or else preserved by careful and frequent painting.

Chapter XXVII.

TIMBER CLASSIFICATION: HARD WOODS.—NOTES FOR USERS.

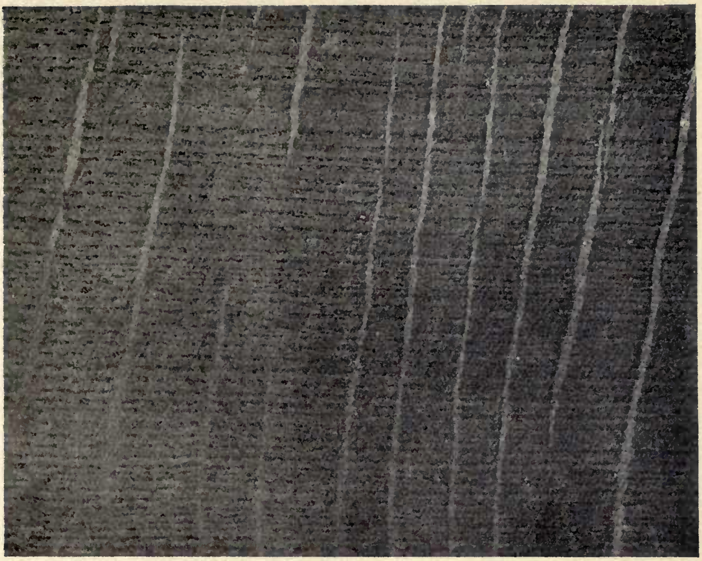
THE hard woods are fortunately free from the extreme confusion in nomenclature from which the soft woods suffer. Each, as a rule, has but one scientific and one popular name, although many of them have several varieties.

OAK.

Oak is unquestionably the most important of the hard woods grown in the temperate zone; though it must be acknowledged that some of the tropical and semi-tropical woods possess such high qualities as to run it very close for many purposes, and to be superior to it in some. It is hard, tough, strong, lasting in air or water, heavy, and obtainable in great lengths and size, and either of straight grain for constructional works, or of most beautiful knotted figure for decorative purposes. The author once measured a squared log, free from imperfections, 42 ft. long, 20 ins. by 16 ins., lying in the Grand Place at Louvain for insertion in the Town Hall there.

The annual rings are distinct, the softer portions being apparently honeycombed, and though the wood is far from porous transversely on account of the hard structure of the cell walls, it is porous laterally along the grain, especially the softer wood grown on loose soil. When cut so as to expose them, the medullary rays are equally distinct, as compact wood with a silky appearance when planed, adding greatly to the beauty of the timber.

It may be painted for external use, but is more frequently only oiled, so as to show its rich colour and grain; while internally it may be, and frequently is, used without



OAK.

SPANISH MAHOGANY.

[To face p. 254.

protective coating of any kind, being left to darken with age, which it does to a rich black. This effect may be artificially obtained by exposing it, after it is wrought and finished, to the fumes of weak ammonia in a closed chamber, the depth of colour depending upon the length of exposure, three days producing a rich mellow tone, only to be reached naturally in some twenty years. This process is known as fumigating.

Oak contains gallic acid, which will rust iron fastenings, hinges, etc., which may come in contact with it.

It is found in the northern hemisphere between the 35th and 60th parallels of latitude; and also in Africa.

Oak thrives in almost any soil except bog and peat, though it prefers a rich loam with underlying clay; and as a rule forest trees are better for conversion than those grown in hedgerows, having a greater length of clear stem.

The most beautiful wood for ornamental purposes, both in colour and grain, is obtained from decaying and hollow trees, and this is usually cut into veneers. It is very hard and practically all heartwood.

The sapwood is greatly inferior to the heartwood, both in strength and durability, and should be rejected for works of any importance.

There are four European varieties of oak, whose timber is practically indistinguishable. They are the—

Quercus Robur Pedunculata (stalk-fruited).	With footstalks of acorns long and those of leaves short. Grows all over Europe within the latitude limits.
Quercus Robur Sessiliflora (stalk-leaved).	With footstalks of acorns short and those of leaves long. Grows all over Europe within latitude limits.
Quercus Pubescens (Durmast).	Fruit and leaves as *Sessiliflora*, but with downy underside of leaves. A somewhat rare timber, and of inferior quality.
Quercus Cerris (mossy-cupped).	With richly serrated leaves and mossy cups to the acorns. Found in Southern Europe only.

It is very generally thought that English-grown oak is the best, and it is generally specified. This is, however, largely a patriotic prejudice which originated before the better class continental timber of the same botanical species was largely imported, or even known; and as a matter of fact true English-grown oak is rarely supplied. That from the Baltic, Spain, and Austria is equally good, there is very much more of it, and it is cheaper, Austria (including Hungary), especially having immense oak forests which can be regularly and commercially worked, while our own oak is only spasmodically grown.

Three different varieties of oak are imported from the American continent, and these are of unequal quality. They may be tabulated as shown on the next page.

The Baltimore and Canadian oaks, the only two to which valid objection can be raised, have been largely imported of late, and are now those which are generally called "American Oak." They are not difficult to detect, owing to their small annual rings, and to their turning red in colour if kept covered up for a few weeks. This does not occur with the *Quercus Alba*, which is equally an American oak, but to which there can be no objection.

Oak is largely used where rough usage is expected, as in the treads of stairs; where liable to exposure to damp, as in window sills; in heavy constructional works, and wherever shocks are to be expected; and also for durable carved work, for which scarcely any other wood is suitable; and for high-class joinery of all descriptions.

MAHOGANY.

After oak, mahogany ranks highest amongst the hard woods used in building, and deservedly so, as, broadly speaking, it can be used with advantage for almost every description of high constructive and decorative work. The range of sizes and quality, the variety of colour, and the diversity of figure (or absence of it if so required) is extreme.

Thirty feet is not an unusual length, and the squares range from 12 ins. to 50 ins. Much of it is firmly-grown wood,

AMERICAN OAK.

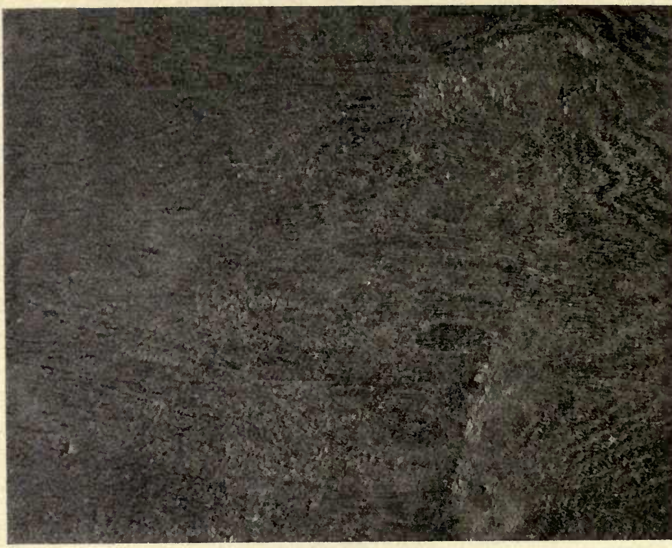
Quercus Alba (White Oak.)	Found between 28° and 48° of North latitude from the east coast of the United States to the State of Illinois.	Very large logs obtainable, but generally from 25 to 40 ft. long, and from 15 to 28 ins. thick.	Pale reddish-brown, straight grained, moderately hard and compact, tough, strong, and fairly durable. Planks can be readily bent when steamed without fear of splitting them. A very sound wood.
Quercus Virens (Live Oak.)	Found principally in the Southern States of North America near the sea coast.	Small timber, not exceeding 18 ft. long by 12 ins. square.	Dark brown, hard, tough, strong, heavy, and difficult to work. Generally of crooked or compass shape, and though the strongest oak known, of little use in building on this account.
Baltimore Oak.	Found in the Mid States of North America.	Straight timber logs from 25 to 40 ft. long, and from 11 to 20 ins. square.	Reddish-brown colour, rather darker than white oak, easy to work, but of little strength—hardly stronger than pine when thoroughly dry. Very slow growth and soon decays, unless well protected from weather.
Quercus Rubra (Canadian Oak).	Found in Canada and the Northern States.	Perfectly straight timber of large growth. Logs vary from 25 to 50 ft. long by 12 to 24 ins. square.	Brown in colour, fine straight grain, somewhat porous, and easy to work. No great strength or durability. Very slow growth and small annual rings.

not too difficult to tool ; it seasons readily with an absence of splitting and checking; it does not warp, and is practically non-inflammable ; and it is capable of receiving a high polish, while as a ground work for paint it is without an

equal. For ornamental purposes it is considered defective in colour when its paleness approaches that of birch, and it may even be too highly coloured, but the best is of a bright ruby appearance. Wood of good quality, firmly grown, is non-porous, and should be fine and free in working, and not too hard. The various figures in the grain are known as "roey," "mottley," "fiddleback," "plum pudding" and "curly." Much that is imported, however, especially that from Africa, is almost free from figure, and even from grain, the annual rings being difficult to distinguish, and if light in colour, as it frequently is, it is then quite inexpensive, and highly valuable for all constructional purposes, especially for sound joinery which is to be painted. The figured varieties, much more costly, are reserved for polished hand-rails, bath-casings, shop-counters, w.-c. seats, etc. All should be thoroughly dried before use.

True mahogany (*Swietenia Mahogani*) grows in the West Indies and Central America, and is a large, handsome tree. Popularly it is known either as "Spanish" (if it come from Cuba, Trinidad or San Domingo); and as "Bay Mahogany" if it come from Honduras. The differences are, however, difficult to detect, although the "Spanish" is the colder to the touch, and has an extremely silky texture with white specks in it—the specks in "Bay" wood being black. For decorative purposes the Spanish is undoubtedly best, having the finer texture and possessing in the more marked degree the property of mellowing and improving in colour with age. The import is, however, diminishing. Much excellent wood of larger size is now being sent over from Tabasco; while smaller, and generally inferior, shipments are also made from Mexico and Panama.

African Mahogany (*Khaya Senegalensis*) is shipped from almost all ports on the West Coast of Africa. The quantity received is simply enormous, representing the product of different districts. The wood of each has its own utility, but probably the following classification will meet approval: —Lagos wood, in colour and silkiness of texture, more



TEAK.

JARRAH.

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closely approximates to the Tabasco shipments, but in size it is generally small. Benin wood affords an excellent range of sizes, and the logs are well squared. The wood, having a splendid texture, commands a leading position. Axim and Assinee wood is usually well squared, and yields enormous sizes ; the colour is generally good, but the texture is softer than other shipments ; it is also found that the logs are more or less liable to cross fractures, which cannot be seen until the logs are cut into. Bathurst wood represents the hardest mahogany from Africa, but the sizes are somewhat small. There are other African ports from which good merchantable timber is shipped, which, however, does not require any special notice ; but Gaboon wood is very little better than birch in colour and texture, and, as a furniture-wood, it should be avoided. Sapeli wood comes in fine, large, well-squared logs, but is scented like cedar, the colour and texture being extremely variable ; it is certainly not growing in favour with buyers, some of whom doubt if the wood is in reality a mahogany.

TEAK.

Teak (*Tectonia Grandis*), while of less beauty than oak or mahogany, is a wood of extreme value, steadily growing in favour. Whilst it is not difficult to tool, it contains an essential oil which renders it imperishable. As it resists the alternations of damp and dryness, heat and cold, there is in it an absence of swelling and shrinking or warping, so that in high-class work there is hardly any purpose to which it could not with advantage be applied. Its general uniformity of colour and grain is unique. Considering the many high essentials found in teak, and the remarkably fine sizes obtainable, both in logs and planks, and the freedom from defects in the latter, it is by no means a dear wood for good work. The logs imported vary from 23 to 50 ft. in length and from 10 to 30 ins. square.

It is of a dark reddish-brown colour, with strongly defined

grain, and is very heavy. It darkens with age, becoming almost black, while when first felled the heartwood is of a dark golden yellow. It is certainly the best weather resisting wood known. In small pieces it may sometimes be mistaken for mahogany and sometimes for oak, but in large pieces it is unmistakable once seen.

The essential oil which it contains acts as a preservative of iron fastenings; but it sometimes congeals in radial shakes, forming a hard substance which no edge-tool can touch without losing its keenness. Teak logs are always heart-shaken.

Teak grows principally in India, ranging from Java on the south to 23° of N. latitude, and from the frontier of China, right across Burmah and Hindustan, the principal shipments being from Moulmein, Rangoon, and Bangkok.

THE LESS IMPORTANT HARD WOODS.

Besides those already mentioned there are no hard woods which are at present largely used in building operations, although there are several which, owing to special qualities either of strength, size obtainable, colour or beauty of marking, are occasionally employed. These may, perhaps, be best arranged in alphabetical order in tabular form, to render reference easy, special attention, however, being called to the Australian Eucalyptus timbers, Karri and Jarrah, which are rapidly growing in favour for many purposes.

Students are advised to obtain specimens of all these woods, and compare them with the descriptions.

DESCRIPTION OF THE LESS IMPORTANT HARD WOODS.

Popular Name.	Botanical Name.	Whence Obtained.	Sizes, etc.	Characteristics.	Uses.
Ash, White Ash, American Ash, Cane Ash	Fraxinus Americana, F. Alba, F. Canadensis, F. Acuminata, F. Discolor, F. Epiptera, F. Lancea	Found from Nova Scotia and Newfoundland to Florida, and from the Atlantic to Ontario, Kansas, and Texas	Logs imported from 14 to 21 ft. long and from 13 to 20 ins. square	Annual rings marked by large open ducts. Excrescences on the trunks, known as "burrs," or "knots," give a rich figure. Light brown, coarse grained, hard and strong. Weighs 40 lbs. per c. ft.	Figured wood employed for veneers.
Ash, Brown Ash, Swamp Ash, Water Ash, Basket Ash	Fraxinus Nigra, F. Sambucifolia	As above	As above	As above.	As above.
Basswood, Lime Tree, Linden, Bee Tree	Tilia Americana, T. Nigra, T. Glabra, T. Latifolia, T. Canadensis, T. Neglecta	North-East United States, and to a slight extent in Canada	Tree about 80 ft. high and 4 ft. dia. when fully grown	Straight grain of annual rings slightly marked by horizontal bands of medullary rays. Light brown colour, sap and heart wood being scarcely distinguishable. Soft, close grained and easily worked. Cracks in seasoning. Weighs 28 lbs. per c. ft.	Cut tangentially into veneers of extreme width (up to 100 ft.) by a special lathe. Not much used.
Beech	Fagus Ferruginea, F. Americana, F. Sylvestris, F. Alba, F. Sylvatica	Canada and North-West United States, especially by the Great Lakes	Trees up to 100 ft. high and 4 ft. dia.	Medullary rays show on cross section, and as silver grain on radial cut. Small black streaks lie along the grain. Heartwood reddish-brown, sapwood white. Weighs 43 lbs. per c. ft. Much subject to worms	Used in the stocks of plane irons, and for rough cabinet work and furniture.

DESCRIPTION OF THE LESS IMPORTANT HARD WOODS—*continue'*.

Popular Name.	Botanical Name.	Whence Obtained.	Sizes, etc.	Characteristics.	Uses.
Birch	Betula Alba B. Papyrifera B. Nigra	Eastern Canada (Quebec, Halifax, and St. John) and Sweden	Planks 2 to 3 ins. thick, 7 to 19 ins. wide, and 10 to 16 ft. long Logs obtainable 18 to 20 ins. square	Straight grain, free from figure of any kind. Hard and tough. Stands wear excellently	Putlogs for scaffolding.
Blackwood	Acacla Melon-oxylon	Australia and Tasmania	Logs up to 26 ft. long and 22 to 28 ins. square	Both straight and wavy grain. Durable and easily worked. Dark brown	A most valuable timber for local use.
Blackwood	Royena Lucida	Cape of Good Hope	As above	Very like above, but yellow colour, striped brown. Takes a good polish	Furniture and musical instruments.
Boxwood	Buxus Semper-virens	South Europe, West Indies, and Australia	Billets 3 to 8 ft. long, 3 to 12 ins. dia.	Close texture, very tough	Mallets and turnery.
Canary-wood	...	...	...	Bright yellow, clean grain and even texture	Joinery which is to be painted or stained.
Chestnut (note that this is the Sweet or Spanish Chestnut and *not* the Horse-Chestnut)	Castanca Vesca	Mid and Southern Europe	...	Somewhat like oak, but with less distinct medullary rays, browner heartwood, whiter sapwood, and broader grain	Fences and palings.
Cottonwood (see Poplar).					
Cucumber tree	Magnolia Acuminata	...	...	Very similar to Whitewood (which see), for which it is often mistaken in the trade	As Whitewood.

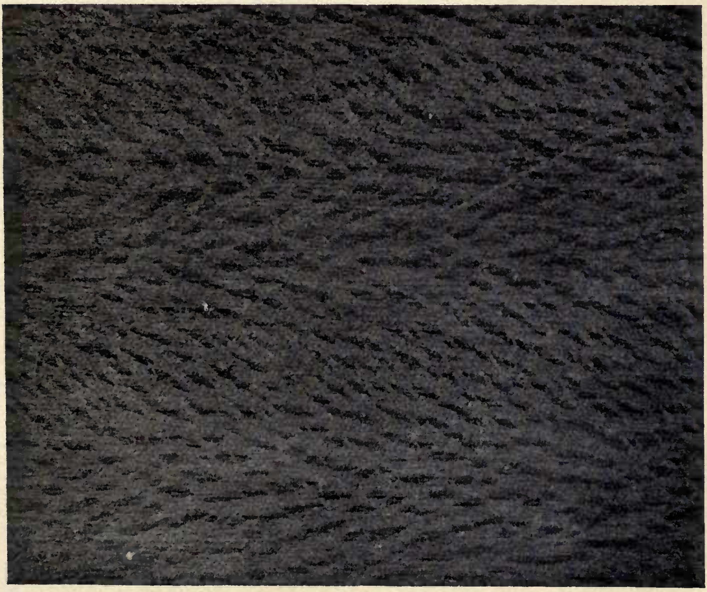
Ebony	Diospyros Ebeneum	The Deccan, the Carnatic, Ceylon, and Madagascar	Very small, up to 3 ft. long	Jet black, close-grained, and very hard. Sapwood grey, striped with black. Weighs 74 lbs. per c. ft. Very durable. Colour in cells and not in cell walls	Inlaying and other ornamental purposes, veneers and mouldings.
Elm (English)	Ulmus Campestris	England and France	Tree up to 80 ft. high and 30 ins. dia.	Brown colour, moderate weight, hard, tough, and porous, with large twisted grain. Difficult to split. Must be used fresh cut, certainly within a year. Most durable if kept entirely dry or entirely wet. Soon decays if subject to changes	At one time largely used for carpentry; now for little save piles in water and damp earth, and for barn sheeting. Used for floors and stairs in France, beeswax polished.
Elm (American)	Ulmus Americana	United States and Canada	Larger than English elm	As above. Takes good polish. Warps and twists in drying	Piles.
Greenheart	Nectandra Rodiœi	Guiana	Logs 24 to 50 ft. long, 12 to 24 ins. square	Clean and straight in grain, very heavy and tough, hard, strong, and elastic. In transverse section it looks like cane, being full of minute pores, with annual rings hardly visible. Dark greenish colour; centre often nearly black. Sap and heartwood difficult to distinguish	Piles in sea water, and wherever heavy shocks are to be resisted.
Hornbeam	Carpinus Betulus	France and South of England	Small	White colour, close, hard, tough, and strong, with minute pores and plainly marked medullary rays. Contains no heartwood	Cogs in machinery, tool handles.
Ironwood* (also known as Lacewood)	Xylia Dolabriformis	Southern India	Tree from 90 ft. to 100 ft. high, 3 ft to 4 ft. dia.	Hard, coarse grained, and beautifully mottled, showing wavy fibres on radial sections. Dark brown, inclining to red. Contains much resin. Weighs 60 lbs. per c. ft.	Piles, railway sleepers, and heavy engineering work generally.

* It may be noted that many hard timbers are locally known as "Ironwood" in different parts of the world.

DESCRIPTION OF THE LESS IMPORTANT HARD WOODS—*continued.*

Popular Name.	Botanical Name.	Whence Obtained.	Sizes, etc.	Characteristics.	Uses.
Jarrah *and* Karri	Eucalyptus Margina a Eucalyptus Diversicolor	Western Australia (south-west portion)	Trees up to 300 ft. high and 10 ft. dia. not unusual. Sawn timber obtainable of any section up to 20 ins. by 12 ins. Logs up to 97 ft. long and 20 ins. square	Two similar and most valuable timbers. Hard, heavy, elastic, and tough. The grain shows that the fibres are interlaced, making it hard to work. Practically non-absorbent and non-inflammable. Free from knots. Looks like red indiarubber and retains colour if oiled or varnished, but weathers grey like oak. Takes a high polish. Extremely durable. Karri is the stronger	Largely used for paving carriage-ways, and more recently for fencing, flooring, and all kinds of high-class joinery and heavy carpentry.
Kingwood or Violetwood	...	French Guiana	...	A large wavy-grained wood of rich and varied colour	Ornamental door-handles, veneers, and finger-plates.
Lacewood (see Ironwood)					
Lignum Vitæ	Guaiacum Officinale, or Ixora Trifolium, or Acacia Falcata	Jamaica, Cuba, etc., British Guiana, New South Wales	Trees under 30 ft. high Trees 30 to 60 ft. high, 16 ins. to 18 ins. dia. A small shrub	Very hard and heavy. Sinks in water. Weighs 83½ lbs. per c. ft. Very similar Very similar	Door handles, turnery, etc. Do. Do.
Locust Wood	Hymenæa Courbaril	British Guiana	Tree 60 to 80 ft. high, 8 to 9 ft. dia.	Hard and close grained, colour reddish-brown streaked. Does not split or warp, and takes a good polish	Veneers.
Maple	Ace Saccharinum	Eastern Canada and the United States, growing best in the Adirondacks	Tree grows to 100 ft. high and 4 ft. dia.	Very hard, close grained and strong. Straight grain, and wears evenly. Free from knots. Sometimes shows "birds'-eye" markings when cut tangentially by a special lathe. Light brown heartwood and yellow sapwood. Polishes well. A radial section shows straight grain barred across with medullary rays horizontally, these being brown streaks and dots on a silvery background. Weighs 43½ lbs. per c. ft.	Of recent years imported for wood block flooring. The figured wood is cut for veneers.

BIRD'S-EYE MAPLE.



LACEWOOD.

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[illegible]	[illegible]	[illegible]		strong figure. Pores are full of resin. Heartwood is bright red, streaked brown and black; sapwood a greyish colour, and very narrow. On exposure to light the heartwood turns to a clayey brown	railing etc.
Plane Tree (see Sycamore).					
Poplar or Cottonwood	Populus Deltoides (and eleven other species)	Mississippi Valley	Trees 90 to 150 ft. high, 6 to 12 ft. dia. Boards usually 1¼ in. thick, 6 to 24 ins. wide	Soft, easily worked, *not* durable. Twists in seasoning. Tangential sections show medullary rays. Satiny lustre. Not a handsome wood	Inferior flooring.
Poplar (see Whitewood).					
Rosewood	Dalbergia Latifolia	India	Trees not exceeding 22 ins. dia. A rare timber	Heartwood is hard, close grained, very dark purple, streaked longitudinally with black; sapwood yellow, forming a narrow ring	Veneers. Effective as mouldings in relief.
Rosewood	Thespesia Populnea	Africa, Pacific Islands and Tropical Asia	A small tree or shrub	Heartwood hard and dark brown	Furniture and gun-stocks.
Sabicu	Acacia Formosa	Cuba and the West Indies	Timber 20 to 35 ft. long, 11 to 24 ins. square	A remarkably solid wood, with very little sap, and almost entirely free from shakes. Stands exposure well. Liable to contain hidden cross fractures of the fibres	Counter-tops, where hardness is needed.
Sandalwood	Santalum Album	Southern India	A small evergreen tree, not above 32 ins. dia.	Yellowish-brown heartwood, strongly scented. Half the diameter is sapwood, white and scentless. Weighs 60 lbs. per ft. c.	Door-handles, finger-plates, etc.

DESCRIPTION OF THE LESS IMPORTANT HARD WOODS—*continued.*

Popular Name.	Botanical Name.	Whence Obtained.	Sizes, etc.	Characteristics.	Uses.
Satinwood	Chloroxylon Swietenia	Central and Southern India and Ceylon	Logs girth as much as 9 ft., but larger sizes usually hollow	One of the most beautiful woods known. The texture and figure are like those of Spanish mahogany, with a fine satiny lustre showing medullary rays as bright shining plates on radial sections. It is hard and polishes well. Colour, a pale lemon yellow. Weighs 64½ lbs. per c. ft.	For all work of highly ornamental character.
Satinwood	Anthoxylum Caribæum	Bahamas	Small wood	Very hard, *not* strong, brittle, fine-grained, compact and satiny. Light orange colour.	Do.
Satin Walnut; also known as Red Gum, Sweet Gum, Alligator Wood, and Bilsted Gum (not a Walnut at all)	Liquidambar Styraciflua or L. Macrophylla	United States (Missouri basin)	Tree grows to 100 ft. high and 5 ft. dia.	Close grained and compact; hard, but not strong. Takes a good polish, but shrinks and warps badly in seasoning. Bright brown colour tinged with red, somewhat resembling true walnut. Weighs 37 lbs. per c. ft.	Street pavements and ordinary carpentry in U.S.A.
Snakewood	Strychnos Nux-Vomica	India, Burmah, and Ceylon	Small	Shows no annual rings and has no heartwood. Difficult to work, though close grained. Liable to split, twist and warp. Weighs 50 lbs. per c. ft.	Fancy cabinet work.
Snakewood or	Brosimum Aubletu	British Guiana	...	...	Inlaying.

Plane Tree	platanus	United States	[illegible]	... like colour, wears well	Dresser-tops.
Tulip Wood (see White Wood).					
Walnut: Black Walnut, American Walnut	Juglans Nigra	From New England to Texas, and from Michigan to Florida. Grows also in England and in Europe generally, and in West Africa, all from American seeds	Tree from 100 to 150 ft. high, and 6 to 9 ft. dia. Planks from 6 to 15 ft. long, $1\frac{3}{4}$ to 2 ins. thick. Boards $\frac{5}{8}$ to 2 ins. thick	Hard, strong, coarse grained, easy to work, takes a good polish, liable to split if not carefully dried. Heart-wood, a rich dark brown; sap-wood, lighter. The nut oil is used for polishing. Figure not often ornamental, except in the roots and when cut tangentially. Weighs 39 lbs. per c. ft.	Veneers.
Walnut: Butternut	Juglans Cinerea	Do.	Do.	Do.	Do.
White Wood or Tulip Wood (often incorrectly called Poplar)	Liriodendron Tulipifera	United States (Ohio basin)	Tree from 80 to 180 ft. high; 3 ft. 6 ins. to 10 ft. dia. Sold in logs and boards	Light, soft, stiff, and fairly strong; of fine texture and yellow colour. Shrinks in seasoning, but splits little. Works easily and stands well. Best figure is tangential, but radial face is best for ornamental work, the medullary rays showing up crossing the vertical grain in silvery bars	Doors, panels and mouldings. Tangential veneers are sold as Tulip Wood.
Zebra Wood	Omphalobium Lambertl	The Tropics	Small	Stripy	Inlaying.

NOTES FOR USERS.

Hard woods, having much greater cohesion between the fibres than soft woods, may be used in curved as well as straight pieces.

Shrinkage is complicated by the action of the medullary rays, but is generally less than in soft woods.

In constructional work, hard wood should always be used where subject to shocks, as in warehouse doors and storey posts.

Mouldings may be undercut, and carving may be rich and deep, there being ample cohesion to render this possible.

Exposed hard wood may be protected by oiling, varnishing or polishing; but so long as it is kept dry and well ventilated it is exceedingly durable even if unprotected.

Chapter XXVIII.

IRON ORES AND THEIR REDUCTION.

MUCH of the iron ore now used in England is imported from Spain, the richer veins of English ore being mostly worked out or nearly so, that which is left having so small a yield of metal as to be unprofitable. The different kinds of ore and the localities in which they occur, or used to occur, are as follows :—

Name of Ore.	Description.	Where Found.	Yield of Metal.
Clay Ironstone	A carbonate of iron, of clay-like appearance but oölitic structure, with nodules the size of a pin's head in a silicious envelope. Very impure, containing clay, pyrites, and sulphur.	Coal measures of Derbyshire, Staffordshire, Shropshire, Yorkshire, Warwickshire and South Wales, and in the lias formation of the Cleveland District (Yorkshire); also largely imported from Spain.	20 to 30 %. Not profitable below 24 %.
Blackband	Clay ironstone containing 15 to 20 % of bituminous and carbonaceous matter, and consequently easy to smelt.	Lanarkshire and Ayrshire.	40 %
		Durham, Staffordshire, North Wales.	Variable
Red Hæmatite	Oxide of iron, generally in globular or kidney-shaped masses; red in colour.	Carboniferous limestone of Cumberland (Cleator Moor, Whitehaven) Ulverston (Lancashire), and Glamorganshire.	50 % to 60 %

Name of Ore.	Description.	Where Found.	Yield of Metal.
Brown Hæmatite	Hydrated oxide of iron; brown colour.	Forest of Dean (Gloucestershire), Alston Moor (Cumberland), Durham, Devon, Northamptonshire; and in France and Belgium.	50% to 60%
Magnetic	...	Devonshire (very little); and in large quantities in Scandinavia.	
Spathic	Crystallized carbonate of iron, generally mixed with lime.	Weardale (Durham), Exmoor (Devon), Brendon Hill (Somerset).	37%

The most important English ore which is now profitably worked is that from the Cleveland Hills, near Middlesbrough. The best seam, 10 ft. thick, yields 30 per cent. of iron, but this is largely worked out, and much now being smelted yields only 26 per cent. As the cost of reduction rises as the yield diminishes, the limit of profitable working must soon be reached.

At the works of Messrs. Wilsons, Pease & Co., Limited, at Middlesbrough, which are similar to most other smelting works in the country, the ore is first tipped, together with small coal to act as fuel and limestone, in such proportion as is later on required to combine with the impurities in the ore, into large continuous kilns, and there calcined, the process being the same as that of lime-burning. Coke is similarly tipped into bunkers adjoining the kilns.

This roasted ore and limestone and coke is next hoisted to the top of a blast furnace (see Fig. 150) and tipped over its edge into a deep circular V-shaped hopper formed between inwardly inclining plates of C.I. and a central steel cone suspended from a chain by a counterbalance.

When enough has been tipped into the hopper, together with a proportionate amount of coke, the cone is allowed to drop, discharging all that is lying upon it into the furnace, which is kept full to within about 15 ft. of the top, and is only allowed to go out once in several years, for repairs, it being otherwise in continuous work, night and day.

Immediately below the level of the cone is a flue, into which pass the gaseous products of combustion, the valuable part being the inflammable carbon monoxide (C O) from the coke, and this is carried off to heat an air blast. This, at a temperature of some 1,500° Fahr., is forced into the furnace near its floor through small nozzles known as "Tuyeres," surrounded with coils of W.I. pipe, through which water circulates to prevent the sides of the furnace well burning out.

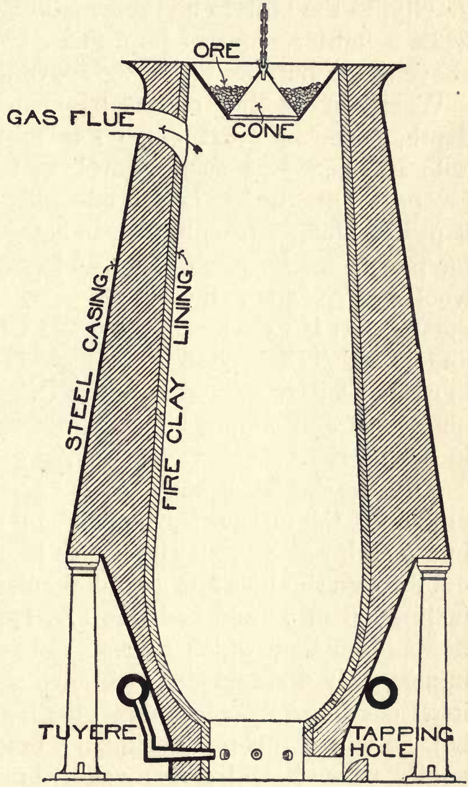


Fig. 150. Blast Furnace.

The furnace is built of brick, much in the shape of a soda-water bottle, with a flat bottom or hearth,

which, like the whole interior, is carefully constructed of fire-brick.

Under the influence of the great heat—some 2,000° Fahr.—which is generated, the ore is reduced and melted, the iron which it contains sinking, from its greater specific gravity, to the bottom and resting directly upon the hearth, while a lighter scum of impurities, known as slag, floats above it, the burning ore being above that again.

When the molten matter has reached to a sufficient depth, never so great as to rise to the tuyere holes, a hole is opened at such a level as to allow the slag to escape. This, which is a crude glass in a molten state, is passed along a trough, and, though some of it is utilised for paving bricks (see p. 207), and some is blown into slag wool (see p. 394), the greater part is valueless, and is either deposited in waste heaps or barged out to sea and dropped in deep water.

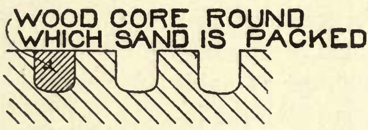


Fig. 151. Section of Pig Channels.

After the slag has been drawn off, the furnace is "tapped" by making a small hole in a fire-clay stopping at its hearth level. Molten iron runs out through this hole into a semi-circular channel made to an inclination in a sand bed (see Fig. 151). With this metal flows some slag, which rises to the surface and is almost immediately diverted along a branch channel, while the iron itself continues its course down the main channel. At the bottom end of this main channel a branch runs off at right angles, which itself has many short branches parallel to the main, each just long enough to hold 1 cwt. of iron when full, known as "pigs." When the branch and the pigs which it feeds are full, another branch a little higher up the main is opened, by breaking down a temporary wall of sand which lay between, and the main itself is blocked with a C.I. "shutter" just below this newly-opened branch; and so on the process continues until all the molten

iron lying in the well of the furnace has been run out into the pigs. The general arrangement on plan is shown in Fig. 152.

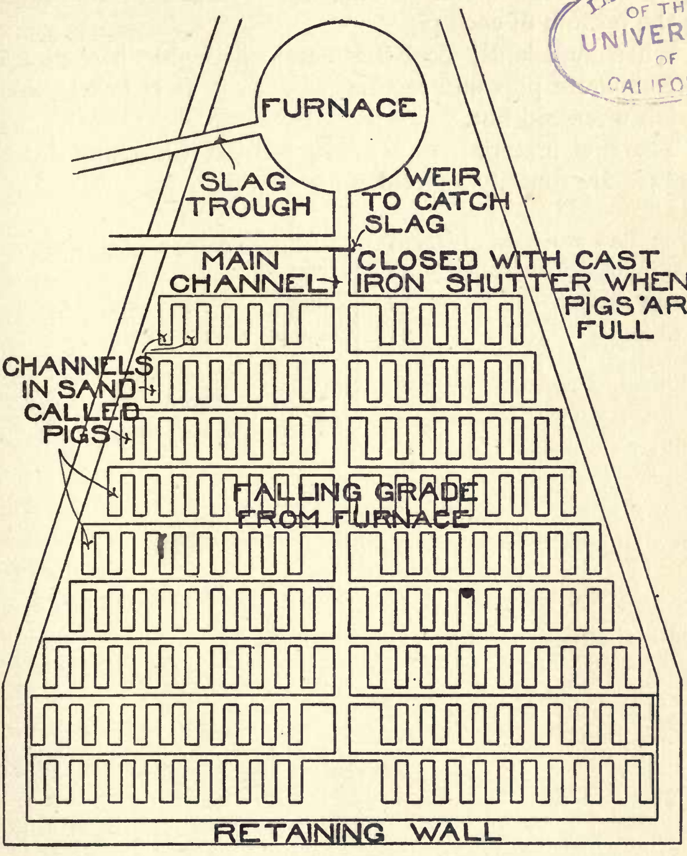


Fig. 152. Plan of Furnace and Sandbed.

The channels, both the smaller ones or pigs, and the larger ones, known as sows, are formed by laying wooden moulds on layers of sand, lying on a sloped platform, and ramming damp sand into the spaces

between the moulds and levelling the surface before the moulds are removed. Initials denoting who are the owners of the furnace, and showing from which furnace of a series the metal is run, are stamped in the sand at the bottom of each pig.

When sufficiently cool the metal is roughly broken up into separate pigs and sections of sows. It is brittle and rough when red hot.

The raw materials and products of a Cleveland blast furnace are roughly as follows :—

Raw materials.	cwts.	Products.	cwts.
Calcined ironstone	48	Iron	20
Limestone ...	12	Slag	35
Coke	21½	Waste, which passes off in the form of gas in combination with introduced air	26½

Chapter XXIX.

MAIN VARIETIES OF IRON: THEIR IMPURITIES, STRENGTH AND TESTS.

IT will readily be understood that pig iron, as run from the blast furnace, is necessarily impure and irregular in its composition, from the intimate manner in which ore, fuel, and flux have been mixed. The principal impurity is carbon, but there are also generally present, in small quantities, silicon, sulphur, phosphorus, and manganese.

So important is carbon that it is upon the proportion of this element contained in the metal that the principal distinction between cast iron, steel, and wrought iron depends.

Roughly speaking—

Cast iron contains from 5 to 2 per cent. of carbon (ideal between 4 and 2 per cent.); steel contains from 2 to ·15 per cent. of carbon (ideal between 2 and ·5 per cent.); wrought iron contains less than ·25 per cent. of carbon (ideal under ·1 per cent.).

Of these three great classes of iron, the following table (on p. 276) shows what may be considered as the leading characteristics—again speaking roughly, and remembering that the classes merge into one another and overlap, the distinctions being sometimes rather those of method of manufacture than of chemical composition, while of each class there are important varieties to be mentioned in greater detail in later chapters.

Cast Iron.	Steel.	Wrought Iron.
Cannot be permanently magnetized.	Can be permanently magnetized.	Can be temporarily magnetized.
Open grained crystalline fracture.	Close grained brilliant crystalline fracture.	Silky fibrous fracture.
Can be melted and cast.	Harder varieties only can be cast.	Cannot be cast.
Cannot be rolled, forged, welded or wire drawn.	Softer varieties only can be rolled, forged, welded and wire drawn.	Can be readily rolled, forged, welded, and wire drawn.
Cannot be tempered...	Can be tempered.	Cannot be tempered.
Snaps suddenly, especially under a sudden blow.	Harder varieties snap suddenly, softer varieties buckle or stretch before breaking.	Gives warning before breaking by first buckling or stretching.
No elasticity	High elasticity.	Moderate elasticity.
When exposed to fire, stands the heat, but snaps suddenly if water touches it while hot.	Buckles, twists, and expands when exposed to fire, but does not break.	Buckles, twists, and expands when exposed to fire, but does not break.

The following, though a different classification from that usual in England, may sometimes be useful. It is based upon that which is official in Germany :—

Crude Iron.	Malleable Iron.
Contains over 2·3 per cent. of impurities, generally 9 to 10 per cent., of which from 2 to 5 per cent. is carbon and the rest silicon and phosphorus; melts without passing through any well-marked pasty stage, and is therefore not malleable; brittle at the ordinary temperature.	Contains a smaller proportion than 2·3 per cent. of impurities, chiefly carbon, generally under 1 per cent.; higher fusing point than crude iron, increasing as the impurities decrease; softens gradually on heating up to its fusing point, and is therefore malleable. Those kinds which are markedly poor in impurities are malleable when cold.
A. *Grey Iron.*—The bulk of the carbon is graphitic, giving a grey fracture.	A. *Puddled Iron.*—Prepared in a pasty, imperfectly fused state, therefore not homogeneous; contains intermixed slag. Varieties containing more carbon are called *Puddled Steel.*
B. *White Iron.*—The bulk of the carbon is combined, and is not present as graphitic carbon.	B. *Ingot Iron* (*Mild Steel*).—Prepared perfectly fluid therefore homogeneous; contains intermixed slag. The harder varieties, containing more carbon and used for large steel castings, may be called *Ingot Steel.*
C. *Spiegel-Eisen* and *Ferro-Manganese.*	C. Special varieties, including *Malleable Cast Iron* and *Temper Steel*—e.g., *Cementation Steel.*

The effect of impurities other than carbon is worth noting, though of more importance to the manufacturer than the user, who, so long as he obtains a material which will do the work he requires, does not mind much how it is composed. The following table is therefore rather of interest than value to the constructor:—

—	Cast Iron.	Steel.	Wrought Iron.
Silicon	Effect similar to that of carbon. Also makes it more fluid when melted, *i.e.*, less viscous.	·02 per cent. makes it cool and solidify without bubbling. More makes it brittle. ·5 per cent. makes it unforgeable.	Makes it hard and brittle.
Phosphorus ...	Reduces tenacity, hardens, renders fusible.	·1 per cent. makes it cold, short and useless for tools. Most injurious.	Injurious. ·1 per cent. makes it more weldable. 1 per cent. makes it too brittle for use.
Manganese ...	Tends to produce white variety.	Essential in mild steel to counteract sulphur.	Counteracts red shortness.
Sulphur	Tends to produce white and mottled varieties.	More than ·2 per cent. unfits it for forging, but makes it more fluid and suited for coating.	·3 per cent. produces red shortness.

In ordinary structural work the following are the approximate data upon which calculations for strength should be based:—

——	Cast Iron.	Cast Steel.	Mild Steel.	Wrought Iron.
Ultimate resistance to compression.	32 tons.	40 tons.	30 tons.	16 tons.
Safe load in compression	8 ,,	10 ,,	7½ ,,	4 ,,
Ultimate resistance to tension.	9 ,,	Not used in tension.	30 ,,	20 ,,
Safe load in tension ...	1½ ,,	Do.	7½ ,,	5 ,,
Ultimate resistance to shearing	8 ,,	Not used in shear.	24 ,,	20 ,,
Safe load in shear	1½ ,,	Do.	6 ,,	5 ,,
Elastic limit or yield point	Scarcely distinguishable from ultimate resistance.	20 tons.	15 ,,	11 ,,
Modulus of rupture per square inch.	40,000 lbs.	...	60,000 lbs.	42,000 lbs.
Modulus of elasticity per square inch.	17,000,000 lbs.	...	30,000,000 lbs.	29,000,000 lbs.
Weight per foot super one inch thick.	38 lbs.	43 lbs.	42 lbs.	40 lbs.

TABLE OF TESTS FOR CAST IRON.

Test Bars, 3 ft. 6 ins. long by 2 ins. deep and 1 in. wide, set on bearings 3 ft. apart, and the Test-load assumed to be hung in centre of span.

N.B.—The Test-load should be supported without fracture, the deflection named being that due to this test load.

Description of Material.	Test Load.	Minimum Deflection.
	Cwts.	
Ordinary quality, suitable for medium-sized columns, etc., and steady loadings	25	...
Good quality, suitable for large or light columns, bressummers, etc.	28	$\frac{1}{4}$ in.
Special quality, where sudden shocks or extra stresses may arise, as in beams carrying heavy live loads, machine castings, high pressure pipes, etc.	30	$\frac{5}{16}$ in.

Castings should also be tested by tapping them lightly with a hammer all over in order to detect, by the sound, the presence of any air bubbles, cracks, or hollows filled with the sand used in casting.

TABLE OF TESTS FOR MILD STEEL.

All Shapes of Bars or Plates.			
Quality.	Tension.		Elongation.†
	Minimum.*	Maximum.*	
			per cent.
Good quality	27	31	20
Special welding quality, suitable for rivets.	26	30	25

* Maximum and minimum tension strains are in tons per square inch of original section.

† Elongation is the percentage of increase in a length of 8 ins.

NOTE.—Contraction of area tests are seldom applied to steel, the elongation being considered a sufficient test for ductility.

The following results of a test upon Whitworth fluid pressed steel show, however, that a better material is obtainable when required for special purposes, though the additional expense of producing it is not generally warranted, it being more economical to use more metal of ordinary quality :—

Diameter of specimen ·7979 in. =	·5 sq. in. area.
Length acted upon	2 inches.
Yielding	22 tons per sq. in.
Ultimate strength	38 „ „
Elongation	36 per cent.
Reduction of area	60 „

TABLE OF TESTS FOR WROUGHT IRON.

N.B.—The Tension columns show the Minimum tensile strains in tons per square inch of original section; the Contraction is measured at percentage of original sectional area; and the Elongation at percentage increase in a length of 8 ins.

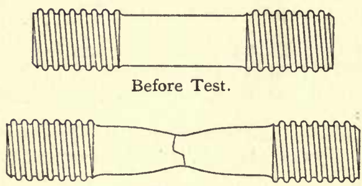
The Medium quality is suited for most ordinary requirements, but where much forging or welding is necessary, "Special Quality" should be specified.

Description.	Medium Quality.			Special Quality.		
	Tension.	Contraction.	Elongation.	Tension.	Contraction.	Elongation.
		per cent.	per cent.		per cent.	per cent.
Rounds, Squares, and Flats.	20	15	10	22 to 23	22	18
Angles, Tees, Channels, etc.	20	15	10	22	20	10
Plates (to $\frac{5}{8}$ in. thickness) lengthways.	20	10	8	21	12	10
Plates across the fibre.	18	5	2	18	6	4

Wrought iron, suitable for rivets, should have a tensile strength of at least 23 tons per square inch with 30 percentage contraction of area. In addition to this, it is often specified that the rivet should be capable of being bent double without cracking, to further prove its ductility.

The test pieces used for these tension tests are circular in section, and, before and after test, have the appearance shown in Fig. 153, which has been made from the actual bar of Whitworth steel referred to on p. 279.

In breaking a specimen of ductile material, such as wrought iron or mild steel, by tension, it is found that before fracture takes place the test piece behaves as a viscous substance (such as pitch or toffee), and flows, being drawn out uniformly until a contraction takes place at the weakest point and fracture occurs. The elongation, or extension, which is thus caused is a measure of the ductility of the material; but in judging this quality, regard must be had to the length of the specimen used, as it is found that of two test pieces of the same material, but of different lengths, the shorter will give the higher percentage of elongation; and similarly, other things being equal, the thicker the test piece, the greater is the percentage of elongation. It is now usual to make the test pieces 8 ins. long and of ·7979 in. diameter, having a sectional area of ·5 sq. in.



Before Test.

After Test.

Fig. 153. Piece of Whitworth Steel.

Furthermore, ductile materials such as these, when subjected to a gradually increasing load, as in a testing machine, carry the load up to a certain point with trifling elongation, and return to their original dimensions on removal of their load. In other words, they are perfectly elastic up to that certain point, which is generally known as their "elastic limit," or "yield point." On further increasing the load, however, the material "breaks down": it begins to stretch to a more marked degree and does not come back on removal of the load. The effect appears to be cumulative. If a load, in excess of the yield point, be applied and removed, stretching occurs, and if the load be applied again, further stretching occurs, with the inevitable

result of eventual fracture if the process be repeated too frequently. Consequently in considering the strength of materials for structural purposes, the *yield point should be taken as the measure of their tenacity* and not the ultimate tensile strength, a point which can scarcely be emphasised too strongly ; but ordinary practice is the reverse of this. The use of a sufficiently high factor of safety, and consequently of a sufficiently low working or safe load, puts this right.

Repeated alternating stresses, the material being alternately in tension and in compression, have also a weakening effect, even if they be well below the yield point individually, but the nature of this effect is not yet quite clear.

COLD BENDING TESTS FOR SHEETS.

(A convenient size for the test pieces is 8 ins. by 6 ins.)

Thickness of Sheet.	Steel. With or across the Grain.	Wrought Iron. With the Grain.	Wrought Iron. Across the Grain.	Remarks.
No. 22 Birmingham Wire Gauge and under.	To bend double round twice its own thickness.			
No. 16 to No. 21 B. W. G.	130°	130°	80°	The inner radius of curve at bend not to exceed $1\frac{1}{2}$ times the thickness of the sheet.
Exceeding No. 16 B. W. G., up to $\frac{1}{8}$ in. in thickness.	110°	110°	60°	
Exceeding $\frac{1}{8}$ in., up to $\frac{3}{16}$ in.	90°	90°	40°	

Chapter XXX.

CAST IRON AND CASTING—NOTES FOR USERS.

WHEN the crude iron is run from the blast furnace into sand moulds, forming pig iron, a portion of the carbon taken up in the furnaces separates out in the form of graphite. Some of this floats to the surface and is removable, but the rest remains incorporated in the iron.

Furnaces which work with silicious ores, and with a large percentage of fuel at a high temperature, produce a metal containing silicon, which assists the crystallization of the contained carbon. The result is GREY CAST IRON, which displays a grey fracture showing distinct crystals of graphite and a large, dark and bright grain. It is readily fusible, runs well into moulds, and is most suitable for delicate castings, but of no great strength. It is also used for conversion into steel. Its specific gravity is 7·1.

Where the opposite conditions prevail, of furnaces working with non-siliceous ores, with a low percentage of fuel and low temperature, the resulting metal contains little silicon and the contained carbon does not crystallize. The result is WHITE CAST IRON, having a fracture of silvery hue, hard and brittle, and of little use for castings, except the very commonest, such as sash-weights. It is principally used for conversion into wrought iron. Its specific gravity is 7·5.

MOTTLED CAST IRON lies between the grey and the white, or, more accurately speaking, contains both.

When treated with nitric acid, the fracture of grey iron shows a black stain, while the stain on white iron will be brown.

Grey iron may be converted into white by suddenly cooling it. It is thus rendered brittle and hard, and advantage of this fact is sometimes taken to give a hard surface to a grey casting by embedding massive cold iron in the sand of the mould, so as to be in contact with those parts which it is desired to "chill."

Similarly white iron may to a certain extent be converted into grey iron by reheating and gradually cooling it; but it must be remembered that these changes do not affect the composition of the alloy, which normally is as follows:—

—	Grey.	White.
	Per cent.	Per cent.
Graphitic carbon	3·30	...
Combined carbon	0·20	3·20
Silicon	3·50	0·64
Phosphorus	0·98	1·32
Sulphur	0·02	0·20*
Manganese	1·58	0·60
Iron (by difference)	90·42	94·04
	100·00	100·00

* NOTE.—The percentage of sulphur in white iron is generally greater than this.

When it is required to confer toughness on small cast iron articles of complex form, they are embedded in hæmatite and heated for several days, and are thereby rendered malleable.

By modifying the working of the blast furnace, and by the use of different ores, other important forms of crude iron are obtainable, including FERRO-SILICON, a light coloured glazy iron, rich in silicon, useful for mixing with white pigs in the "cupola" in order to produce grey iron; and SPIEGEL-EISEN (mirror iron), an alloy of crystalline structure and lustrous appearance, containing a considerable amount (generally about 10 per cent.) of manganese, and consequently more carbon than does the normal pig. When the proportion of manganese is largely increased, up to a

possible maximum of 85 per cent., the metal is called FERRO-MANGANESE. These manganitic pigs are both used in steel making, and so also, to a less extent, are FERRO-CHROMIUM, containing 60 to 70 per cent. of chromium; and PHOSPHORIC IRON, containing as much as 7 per cent of phosphorus.

For foundry purposes, pig iron is remelted in a "cupola" —this somewhat misleading name being given to a small vertical blast furnace (see Fig. 154), worked intermittently with a cold blast. It is about 5 ft. diameter internally, and lined with fire-brick. Almost invariably advantage is taken of this opportunity to mix pigs of various classes, with the result that any desired quality of cast iron can be obtained. The oxidation of silicon would occur in this furnace, to the detriment of the casting, were it not prevented by the presence of manganese, which is the first impurity to oxidize when crude iron is remelted; while grey iron, rich in graphitic carbon, is improved by being mixed with poorer varieties when used for castings.

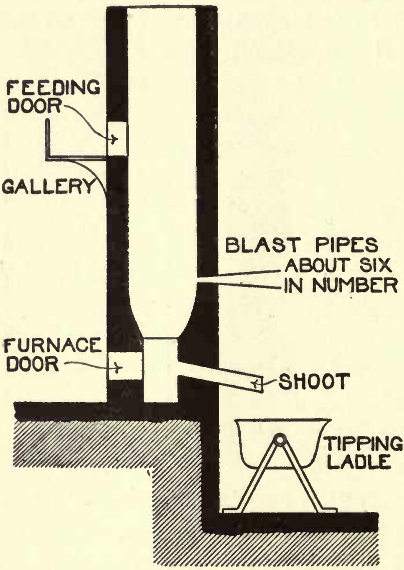


Fig. 154. Cupola.

The pigs and coke are fed into an upper door from a gallery, are melted in the furnace, falling on to the hearth, where a scum of slag collects and is removed as in the blast furnace, while the molten metal is poured out through

a shoot, in appearance like a stream of golden water, into a tipping ladle, whence it is poured into smaller ladles carried by one, two or more men (according to their size) to the moulds.

The preparation of the moulds and the process of casting is long, difficult, and often complicated; and it is unnecessary to go into the matter here in detail, though a general description may be useful.

In the first place, a pattern or model of the object which it is desired to cast is made of wood (or of metal if a large number of duplicates are required), a trifle larger than the finished object, to allow for shrinkage in cooling. Frequently a pattern has to be in several pieces, to allow of its subsequent removal in sections from the sand mould; and often these pieces are alternative where slight variations from a general model are required.

For simple castings of small or moderate size, the pattern is placed on its side in the lower of a pair of square frames without top or bottom, known as flasks, so that half of it rises above the level of the top of the flask; and then fine, loamy sand in a damp condition is tightly rammed into the flask round it.* The surface of the sand is smoothed level with the top of the flask, and sprinkled over, together with the visible half of the pattern, with dry or "parting" sand. The upper flask is then lowered so as to fit upon the lower half, to which it is bolted, and damp sand is again packed in, over and around the pattern. When full, the upper flask can be lifted off, carrying with it the tightly-packed damp sand which it contains, but not the dry parting sand nor the pattern, which can be lifted out carefully.

For many purposes the flasks are dispensed with and the pattern is sunk in the floor of the foundry, and there packed round with sand or even roughly built in with brickwork before the sand is packed; while for special purposes specially shaped flasks are used.

* See illustrations, Figs. 173 and 174, to the Chapter on "Brass," where the process is again referred to.

In either case, the mould left on removal of the pattern frequently requires touching up and finishing by hand—an extremely delicate operation; and when sharp castings are needed it is dusted with powdered charcoal and carefully smoothed. This also prevents the iron from being chilled by too close contact with the damp sand, as a cushion of gas is formed when the metal is poured in.

Finally, holes are carefully made through which the contained air of the mould and any produced gases may escape, and for the pouring in of the metal; the flasks are closed; and the metal is poured in—great care being exercised in the case of large castings, where more than one ladle of metal is used, that the pouring is continuous; and if more than one pouring hole is used, that two streams of metal shall not meet when in the smallest degree cooled; otherwise a weak spot, or joint, known as a "cold-shut," will be produced.

As bubbles form and rise to the surface during casting, it is well that the metal be poured in to the very top of the mould, and that a "head" of metal, afterwards to be cut off, be cast, into which such bubbles may collect.

Hollow objects, such as columns and pipes, have to be cast round a solid core, which frequently itself consists of a pipe perforated with many holes, round which damp sand is carefully worked to the desired shape. Theoretically such objects should be cast vertically, but this is rarely possible, and they are generally laid to a slight inclination and cast with a head. The core is, in large columns and long pipes, difficult to fix and retain in position so as to give uniform thickness of metal throughout. Often the core is connected to the outer sand of the mould with iron wire or nails, which, when the hot metal is poured in, are firmly embedded in it.

Castings should be left in the sand mould to cool gradually, else irregular cooling is likely to occur, or too rapid cooling of the outside, eventuating in cracks, as strains are set up in the already cooled portions by the

cooling and consequent contraction of the remainder. Similarly, sudden changes of form, and particularly sudden changes in the thickness of the metal in a casting, are likely to result in breakage, the thinner portions cooling much more rapidly than those which are thicker. So far as is practicable, the same thickness of metal should be retained throughout, but if a change is necessary, it should be made gradually. All angles, particularly internal angles, should be rounded. In cooling, the metal is apt to arrange itself in lines parallel with the adjacent surfaces, so that sharp angles result in indefinite mitres in the metal itself, and these are sources of weakness.

NOTES FOR USERS.

Cast iron can be made into almost any conceivable form of which a pattern or mould can be made.

It is most valuable in positions where continuous compression is to be resisted, but its resistance to tension is slight, as is also its resistance to shocks.

It cannot be twisted, or worked under the hammer, or welded, or riveted. Pieces can only be joined together by the use of screws, collars or bolts.

It is much used for common gates and railings, but is very liable to break, and it is rarely used where special designs are called for, when wrought iron would be cheaper (owing to the cost of preparing a pattern), and more durable.

Regular painting is essential as a preservative.

It cracks suddenly, with little or no warning, whether failure be due to shock, over-loading, or exposure to fire.

Chapter XXXI.

WROUGHT IRON—NOTES FOR USERS.

WROUGHT IRON has been almost entirely replaced by mild steel for heavy structural work, but it is still much used for conversion into hard steel and for small forgings, and particularly for ornamental work, where a tough material, easily handled, bent, or welded is required. Chemically, even in respect to the quantity of contained carbon, it does not greatly differ from mild steel, and in fact, the two often overlap ; but its method of manufacture is entirely different, and the resulting material has very different properties.

White, mottled, or hard grey pig iron is loaded and melted upon the hearth of a reverberatory furnace, such as is shown in longitudinal section in Fig. 155. When molten, slags containing oxide of iron are introduced, with the result that the carbon in the pig iron combines with the oxygen they supply, bubbling or boiling off as CO, which ignites, and so assists to raise the temperature of the furnace, this being necessary as the melting temperature of the metal steadily rises as the proportion of contained carbon diminishes. Before long, however, this can go no further, the boiling ceases owing to the carbon having been nearly eliminated, and the metal collects in lumps in a sticky condition. These lumps are brought together with rakes, worked through a side door, and the ball thus made is withdrawn from the furnace, the whole process being known as "puddling." It is then compressed, either by blows from a steam hammer, or by means of a squeezer which acts like the upper arm of a pair of nut-crackers against a bed-plate.

In this way the greater part of the contained slag is

squeezed out, and the bloom thus formed is passed between rollers to further consolidate it, the result being known as "puddled" bar. This is cut into short lengths, which are "piled," or tied together with wire, reheated, again in a

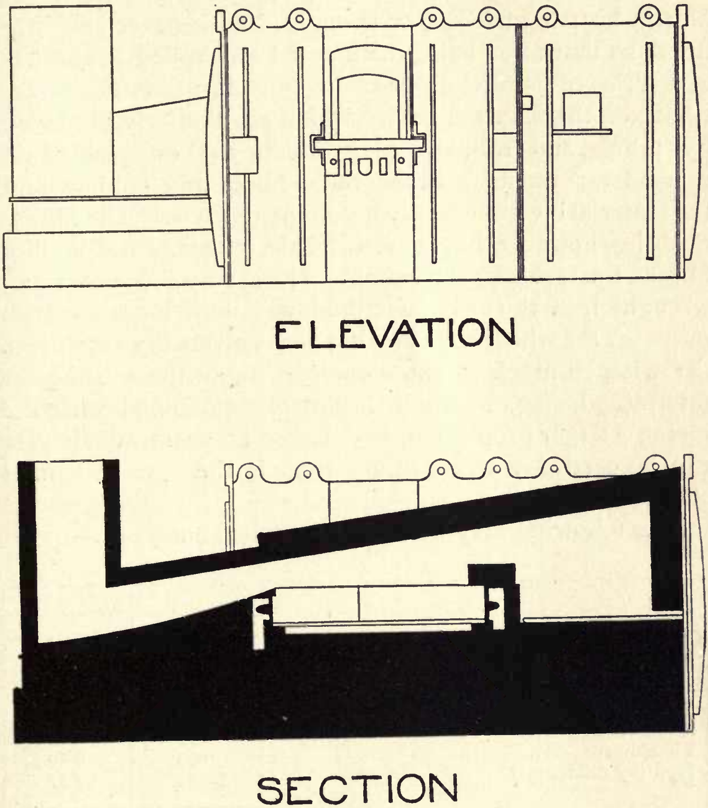


Fig. 155. Reverberatory Furnace.

reverberatory furnace, and again hammered and rolled, when it is known as "merchant" bar. Repetition of the process produces "best" bar, which is followed by "best best," and "best best best."

If the puddling be stopped at a stage short of the complete

elimination of the carbon, "puddled steel" is produced, but this is rarely done, owing to the difficulty of obtaining exact proportions.

The temperature in a reverberatory furnace being considerably less than in a Bessemer converter or a Siemens-Martin hearth, puddled, or wrought, iron is never perfectly fused, so that after being hammered and rolled it consists of a series of parallel fibres arranged to form laminæ, somewhat like the flakes of pastry which are similarly produced by piling and rolling. Slag which has escaped being pressed out exists between these fibres and laminæ, and the material is consequently not homogeneous. The higher qualities, however, have considerable tenacity, and a silky fibrous fracture of grey colour. Until very few years ago wrought iron thus manufactured was used for almost all purposes for which mild steel is now universally employed.

Owing to much of the contained impurities existing as intermixed slag, and not intimately combined with the metal, a larger proportion, as detected by chemical analysis, can be carried without injury than is the case with mild steel.

The following may be taken as typical analyses :—

	Puddled Bar.	Wrought Iron.
	Per cent.	Per cent.
Carbon	0·10	0·06
Silicon	0·13	0·04
Manganese	0·08	0·08
Sulphur	0·05	0·05
Phosphorus	0·35	0·20
Iron (by difference)	99·29	99·57
	100·00	100·00

NOTES FOR USERS.

Wrought iron is obtainable in plates, rectangular bars or circular rods, and may be cut, twisted, and bent in any

direction or hammered out flat, or into bulbous knobs; but it cannot be obtained in mass.

Pieces can be joined together by welding (beating together while hot), or by riveting, or by means of wrought-iron collars, but as a rule the joints form weak spots.

Wrought iron shrinks as it cools, and advantage of this can often be taken to produce very tight connections, a collar, for instance, being put on hot and allowed to cool on.

Only such forms are obtainable, either for construction or ornament, as can be made by hammering, cutting, and planing. Complicated designs have to be built up of many small pieces, each separately formed.

It resists shocks admirably, and so is most suitable for gates and railings; but it rusts readily, and should be kept well painted if used externally.

It should not be used in contact with oak, the gallic acid in which attacks the metal, nor in contact with other metals, such as copper, with which a galvanic circuit would be completed in presence of moisture.

It bends and twists if exposed to great heat, but bends before it breaks, and so gives warning at all times of impending failure.

Chapter XXXII.

MILD STEEL.

THERE is another important method of manufacturing hard (or true) steel, such as tool steel, known as the CEMENTATION process, but it is not intended to do more than refer to it here. We may, however, note that by its means steel is produced from wrought iron. Our attention will be confined to the BESSEMER and the SIEMENS-MARTIN processes, which alone are employed for the production of the mild steel (more properly called Ingot Iron) used in structural work.

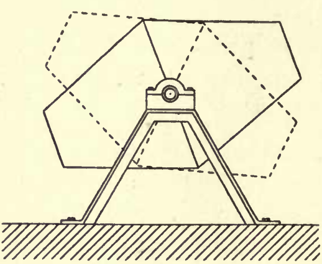


Fig. 156. Rocker.

Both these processes can be worked as either acid or basic. As originally designed, the Bessemer converter was lined with ganister, a highly siliceous material, refractory at high temperatures and acid in character. This only allows of the use of pure hæmatite ores, as others contain phosphorus, and this can only be eliminated freely in the presence of a base capable of forming a stable phosphate with the oxidized phosphorus. As non-phosphoric ores are comparatively rare and costly, a basic lining is therefore more commonly used, consisting of dolomite, and to produce the best results with such a lining the ore should not only contain phosphorus, but this element should be present to a fairly rich extent.

In the basic Bessemer process, as seen at the works of Messrs. Bolckow, Vaughan & Co., Limited, at Middlesbrough,

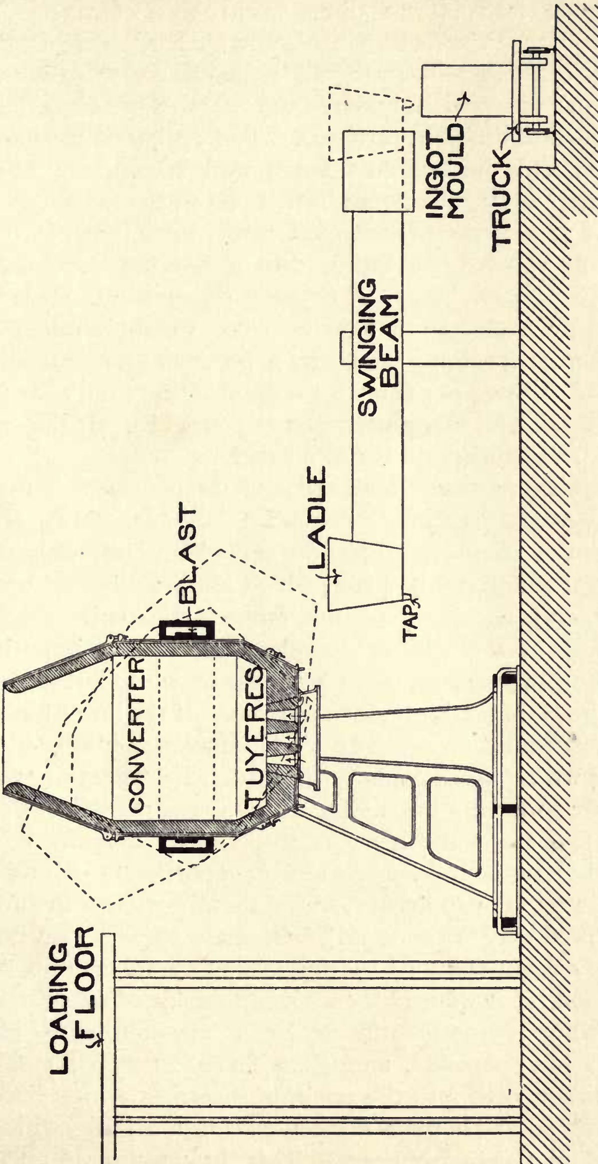


Fig. 157. Bessemer Converter, Ladle, and Ingot Mould.

the crude iron is run direct from blast furnaces into ladles of large size, which are conveyed by small engines on trucks along railway metals to a mixer, or *rocker* (see Fig. 156), into which is poured the contents of several ladles from several different furnaces. The rocker is then set in motion, and the contents, when well mixed, are poured into another large ladle and conveyed to the *converter*.

This is a large pear-shaped contrivance (see Fig. 157), hung to revolve vertically, with a hot blast introduced through "tuyere" holes at or near the bottom. It is first heated by a charge of burning coke, which is raked out, and then, if its lining be basic, a proportion of quicklime, of from 10 to 15 per cent. by weight of the total charge, is introduced, and the molten iron is poured in. If the lining be acid, the quicklime is not needed.

The blast is now introduced, and the converter is turned into a vertical position. The blast is continued for about eighteen or twenty minutes, during which time important chemical changes take place, which can be followed by the colour and character of the flame and sparks emitted, resulting in the almost complete removal of impurities, including the carbon, when a stream of white-hot nitrogen from the air of the blast alone escapes. If the lining be basic this is continued for a short period known as the "after-blow," during which the phosphorus is oxidized and combines with the lime to form a basic slag, which is poured off.

At this stage the blast is stopped for a moment, and spiegel-eisen, containing a known proportion of carbon and manganese, is introduced; or, if a metal very low in carbon is required (say ·25 per cent.), ferro-manganese is substituted for the spiegel-eisen, as by this means a smaller proportion of carbon is introduced for a given amount of manganese.

Blowing is now continued for a few minutes to effect perfect incorporation, and then finally stopped, and the converter turned into the position shown in dotted lines in Fig. 157, so as to pour the contents into a ladle, which is carried on a swinging beam. This is swung round, and the

contents of the ladle are poured into large iron moulds, which stand upright upon railway trucks. Before long the metal cools sufficiently to stand by itself, when the mould is removed, and the truck is taken away with a glowing "ingot" of red-hot steel standing upon it, possibly 6 ft. high and 18 ins. square.

The proportions of impurities present at various stages may be seen from the following table:—

—	Bessemer Acid Process.			Bessemer Basic Process.			Basic Siemens-Martin Process (Finished Metal).
	Bessemer Pig.	Metal at end of Blow.	After addition of Spiegel Eisen.	Basic Pig.	Metal at end of After-blow.	Finished Metal.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon ...	3·57	0·19	0·37	3·57	trace	0·12	0·17
Silicon ...	2·26	trace	trace	1·70	trace	0·03	0·02
Manganese ...	0·04	trace	0·54	0·71	trace	0·27	0·04
Sulphur ...	0·10	0·10	0·09	0·06	0·05	0·04	0·01
Phosphorus ...	0·07	0·07	0·05	1·57	0.08	0·02	0·06
Iron (by difference).	93·96	99·64	98·95	92·39	99·87	99·52	99·70
	100·00	100·00	100·00	100·00	100·00	100·00	100 00

At the works of Messrs. Dorman, Long & Co., Limited, at Middlesbrough, steel is produced by the Siemens-Martin, or Open-hearth process, from a mixture of pig iron, scrap, and ore. The furnace used is that known as a *regenerator* (see Fig. 158), heated with "Producer Gas," of which 34·4 per cent. is carbon monoxide (CO) and the remainder nitrogen (N). When in work, heated air and heated gas are introduced where shown on the plan, and pass by way of the passages marked *a* and *g* respectively, and then up through the regenerators C and B (which are chambers packed with chequer-work of fire-brick). The air and gas meet as they enter the combustion chamber on Hearth A, which they sweep over in a state of combustion at an extremely high temperature, passing out through the

regenerators D and E to the passages *a* and *g*, and thence to the smoke flue F. Every few minutes the valves V and V are reversed, and the blast is thus caused to pass in the opposite direction across the hearth and through the regenerators, which are thus alternately cooled while heating the already hot air and gas, and heated while cooling the products of combustion. The hearth of the furnace, A, is made of iron plates kept cool by the circulation of air beneath them, packed, in the acid process, with highly silicious sand, or in the basic process with dolomite or magnesite burnt and ground with tar.

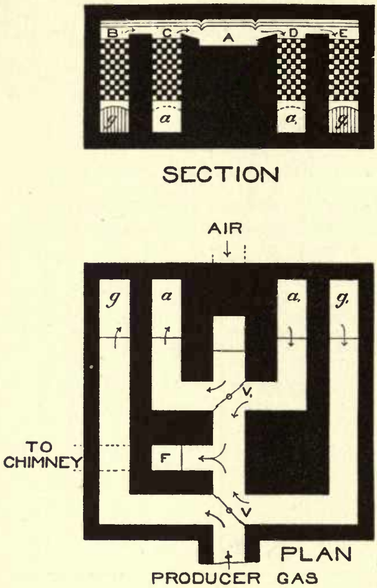


Fig. 158. Regenerator.

When the furnace is white-hot it is charged with pig iron, and when this is fused scrap iron or ore, or both, is added, the pig iron being phosphoric if the hearth be basic, in which case also lime is added to the bath.

Complete control is possible; and when all impurities have been removed, ferro-manganese is added, as in the Bessemer process, to give the exact proportion of carbon required, and the metal is then poured into ladles and thence into ingot moulds.

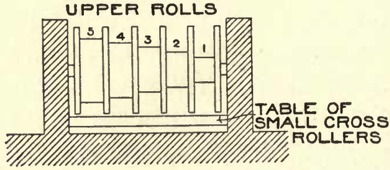


Fig. 159. Steel-Rolling Mills.

By whichever process the ingots have been produced, they are next reheated to a white heat in either vertical or horizontal furnaces, and are then passed lengthwise between steel rollers, of which a simple set is shown in Fig. 159. The ingot is placed on the table of small lower rollers, and guided as they convey it under one of the grooves of the large upper roller. The way in which the rollers revolve is reversed, so that the ingot passes alternately forwards and backwards, first through groove 1, then through groove 2, and so on, being squeezed to a smaller section and greater length each time.

After passing through this simple set of rollers, the "bloom," as it is now called, is cut into suitable lengths, and the lengths passed between further rollers, of which the upper and lower sets are now usually of the same diameter, and both grooved, gradually changing the form of the bar until the finished section is obtained, be it rod, plate, joist, T, or angle iron.

The following list of market sizes is taken from the catalogue of Messrs. Dorman, Long & Co., Limited, and may vary with other manufacturers; but the beams (or joists) are standardised, and should be obtainable anywhere:—

Sizes of Steel Bars.

Note.—All the dimensions given are in inches.

Rounds (see Fig. 160) $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{8}$, $1\frac{1}{4}$, $1\frac{3}{8}$, $1\frac{1}{2}$, $1\frac{5}{8}$, $1\frac{3}{4}$, $1\frac{7}{8}$, 2, $2\frac{1}{8}$, $2\frac{1}{4}$, $2\frac{3}{8}$, $2\frac{1}{2}$, $2\frac{5}{8}$, $2\frac{3}{4}$, $2\frac{7}{8}$, 3, $3\frac{1}{8}$, $3\frac{1}{4}$, $3\frac{3}{8}$, $3\frac{1}{2}$, $3\frac{5}{8}$, $3\frac{3}{4}$, $3\frac{7}{8}$, 4, and rising by $\frac{1}{4}$ in. to 8 ins.

Fig. 160.

Squares (see Fig. 161) $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{8}$, $1\frac{1}{4}$, $1\frac{3}{8}$, $1\frac{1}{2}$, $1\frac{5}{8}$, $1\frac{3}{4}$, $1\frac{7}{8}$, 2, $2\frac{1}{8}$, $2\frac{1}{4}$, $2\frac{3}{8}$, $2\frac{1}{2}$, $2\frac{5}{8}$, $2\frac{3}{4}$, $2\frac{7}{8}$, 3, $3\frac{1}{8}$, $3\frac{1}{4}$, $3\frac{3}{8}$, $3\frac{1}{2}$, $3\frac{5}{8}$, $3\frac{3}{4}$, $3\frac{7}{8}$, 4 ins.

Fig. 161

SIZES OF STEEL BARS—*continued.*

Flats (see Fig. 162).

Fig. 162.

Width.	Thickness.	Width.	Thickness.	Width.	Thickness.	Width.	Thickness.
1½	¼ to 1	3	¼ to 1	5	5/16 to 1	10	⅜ to 1
1¾	,,	3¼	,,	5½	,,	11	,,
2	,,	3½	,,	6	,,	12	,,
2¼	,,	3¾	,,	7	⅜ to 1	14	½ to 1
2½	,,	4	,,	8	,,	15	,,
2¾	,,	4½	5/16 to 1	9	,,	16	,,
						18	,,

The following are the British standard sections issued by the Engineering Standards Committee, by whose permission they are published :—

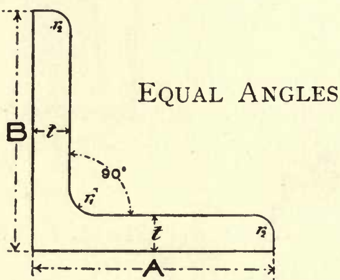


Fig. 163.

Size.	Thickness at Correct Standard Profile.			Radii.		Weight per foot.		Sectional area.	
A × B	Minimum.	Mean.	Maximum.	Root.	Toe.	Min.	Max.	Min.	Max.
	t	t	t	r_1	r_2				
in.	in.	in.	in.	in.	in.	lbs.	lbs.	in.	in.
1 × 1	·125	...	·250	·175	·125	·80	1·49	·234	·437
1¼ × 1¼	·125	...	·250	·200	·150	1·02	1·92	299	·564
1½ × 1½	·125	...	·250	·200	·150	1·23	2·34	·361	·689
1¾ × 1¾	·175	...	·300	·225	·150	1·98	3·27	·583	·961
2 × 2	·175	...	·300	·250	·175	2·28	3·77	·670	1·11

EQUAL ANGLES—*continued.*

Size.	Thickness at Correct Standard Profile.			Radii.		Weight per foot.		Sectional area.	
A × B	Minimum.	Mean.	Maximum.	Root.	Toe.	Min.	Max.	Min.	Max.
	t	t	t	r_1	r_2				
in.	in.	in.	in.	in.	in.	lbs.	lbs.	in.	in.
2¼ × 2¼	·175	...	·300	·250	·175	2·57	4·28	·757	1·26
2½ × 2½	·250	·375	·500	·275	·200	4·04	7·65	1·19	2·25
2¾ × 2¾	·250	·375	·500	·275	·200	4·46	8·50	1·31	2·50
3 × 3	·250	·375	·500	·300	·200	4·90	9·36	1·44	2·75
3½ × 3½	·300	·425	·500	·325	·225	6·84	11·05	2·01	3·25
4 × 4	·300	·425	·500	·350	·250	7·85	12·75	2·31	3·74
4½ × 4½	·375	...	·500	·400	·275	11·00	14·46	3·24	4·25
5 × 5	·375	...	·500	·425	·300	12·27	16·15	3·61	4·75
6 × 6	·450	...	·625	·475	·325	17·68	24·18	5·20	7·11
7 × 7	·500	...	·675	·550	·375	22·97	30·60	6·75	9·00
8 × 8	·550	...	·750	·600	·425	28·89	38·89	8·50	11·44

UNEQUAL ANGLES.

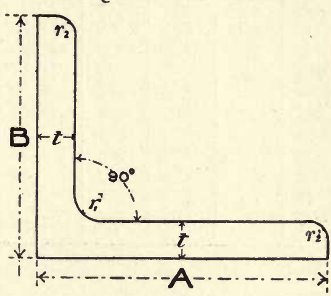


Fig. 164.

Size.	Thickness at Correct Standard Profile.			Radii.		Weight per foot.		Sectional area.	
A × B	Minimum.	Mean.	Maximum.	Root.	Toe.	Min.	Max.	Min.	Max.
	t	t	t	r_1	r_2				
in.	in.	in.	in.	in.	in.	lbs.	lbs.	in.	in.
1¼ × 1	·125	...	·250	·175	·125	·90	1·70	·265	·500
1½ × 1¼	·125	...	·250	·200	·150	1·11	2·12	·327	·624
1¾ × 1½	·175	...	·300	·225	·150	1·83	3·01	·539	·886
2 × 1½	·175	...	·300	·225	·150	1·98	3·27	·583	·961
2½ × 2	·175	...	·300	·250	·175	2·57	4·28	·757	1·26

UNEQUAL ANGLES—*continued.*

Size.	Thickness at Correct Standard Profile.			Radii.		Weight per foot.		Sectional area.	
A × B	Min. t	Mean. t	Max. t	Root. r_1	Toe. r_2	Min.	Max.	Min.	Max.
in.	in.	in.	in.	in.	in.	lbs.	lbs.	in.	in.
3 × 2	·250	·375	·500	·275	·200	4·04	7·65	1·19	2·25
3 × 2½	·250	·375	·500	·275	·200	4·46	8·50	1·37	2·50
3½ × 2½	·250	·375	·500	·300	·200	4·90	9·36	1·44	2·75
3½ × 3	·250	·375	·500	·325	·225	5·31	10·20	1·56	3·30
4 × 2½	·250	·375	·500	·325	·225	5·31	10·20	1·56	3·00
4 × 3	·300	·425	·500	·325	·225	6·84	11·05	2·01	3·25
4 × 3½	·300	·425	·500	·350	·250	7·34	11·90	2·16	3·50
4½ × 3	·300	·425	·500	·350	·250	7·34	11·90	2·16	3·50
4½ × 3½	·300	·425	·500	·350	·250	7·85	12·75	2·31	3·75
5 × 3	·300	·425	·500	·350	·250	7·85	12·75	2·31	3·75
5 × 3½	·375	...	·500	·375	·250	10·37	13·61	3·05	4·00
5 × 4	·375	...	·500	·400	·275	11·00	14·46	3·24	4·25
5½ × 3	·375	...	·500	·375	·250	10·37	13·61	3·05	4·00
5½ × 3½	·375	...	·500	·400	·275	11·00	14·46	3·24	4·25
6 × 3½	·375	...	·500	·400	·275	11·64	15·31	3·42	4·50
6 × 4	·375	...	·500	·425	·300	12·27	16·15	3·61	4·75
6½ × 3½	·375	...	·500	·425	·300	12·27	16·15	3·61	4·75
6½ × 4	...	·525	...	·425	·300	17·81		5·24	
6½ × 4½	...	·550	...	·450	·325	19·54		5·74	
7 × 3½	...	·525	...	·425	·300	17·81		5·24	
7 × 4	...	·550	...	·450	·325	19·54		5·74	
8 × 3½	...	·575	...	·475	·325	21·37		6·28	
8 × 4	...	·625	...	·475	·325	24·18		7·11	
9 × 4	...	·650	...	·500	·350	27·30		8·02	
10 × 4	...	·675	...	·550	·375	30·60		9·00	

Z Bars.

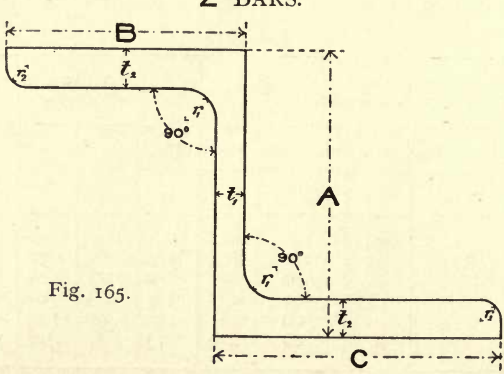


Fig. 165.

Z BARS—*continued.*

Size.	Thickness at Correct Standard Profile.		Radii.		Weight per foot.	Sectional area.
Web and Flanges.	Web.	Flanges.	Root.	Toe.		
A × B × C	t_1	t_2	r_1	r_2		
in.	in.	in.	in.	in.	lbs.	in.
3 × 2½ × 3	·300	·400	·325	·225	9·81	2·88
4 × 2½ × 3	·325	·425	·350	·225	11·53	3·39
5 × 3 × 3	·350	·450	·375	·250	14·17	4·17
6 × 3½ × 3½	·375	·475	·425	·300	17·88	5·26
7 × 3½ × 3½	·400	·500	·450	·300	20·22	5·94
8 × 3½ × 3½	·425	·525	·450	·325	22·68	6·67
9 × 3½ × 3½	·450	·550	·475	·350	25·33	7·45
10 × 3½ × 3½	·475	·575	·500	·350	28·16	8·28

CHANNELS.

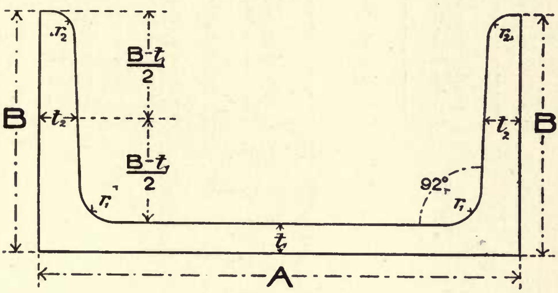


Fig. 166.

Size.	Thickness at Correct Standard Profile.		Radii.		Weight per foot.	Sectional area.
Web and Flanges.	Web.	Flange.	Root.	Toe.		
A × B × B	t_1	t_2	r_1	r_2		
in.	in.	in.	in.	in.	lbs.	in.
3 × 1½ × 1½	·250	·312	·312	·220	5·27	1·55
3½ × 2 × 2	·250	·312	·312	·220	6·75	1·99
4 × 2 × 2	·250	·375	·375	·260	7·96	2·34
5 × 2½ × 2½	·312	·375	·375	·260	10·98	3·23
6 × 2½ × 2½	·312	·375	·375	·260	12·04	3·54
6 × 3 × 3	·312	·437	·437	·300	14·49	4·26
6 × 3 × 3	·375	·475	·475	·325	16·29	4·79
6 × 3½ × 3½	·375	·475	·475	·325	17·90	5·27
7 × 3 × 3	·375	·475	·475	·325	17·56	5·17
7 × 3½ × 3½	·400	·500	·500	·350	20·23	5·95
8 × 2½ × 2½	·312	·437	·437	·300	15·12	4·45

CHANNELS—*continued*.

Size.	Thickness at Correct Standard Profile.		Radii.		Weight per foot.	Sectional area.
Web and Flanges.	Web.	Flange.	Root.	Toe.		
A × B × B	t_1	t_2	r_1	r_2		
in.	in.	in.	in.	in.	lbs.	in.
8 × 3 × 3	·375	·500	·500	·350	19·30	5·67
8 × 3½ × 3½	·425	·525	·525	·375	22·72	6·68
8 × 4 × 4	·450	·550	·550	·375	25·73	7·57
9 × 3 × 3	·375	·437	·437	·350	19·37	5·70
9 × 3½ × 3½	·375	·500	·500	·350	22·27	6·55
9 × 3½ × 3½	·450	·550	·550	·375	25·39	7·47
9 × 4 × 4	·475	·575	·575	·400	28·55	8·40
10 × 3½ × 3½	·375	·500	·500	·350	23·55	6·92
10 × 3½ × 3½	·475	·575	·575	·400	28·21	8·30
10 × 4 × 4	·475	·575	·575	·400	30·16	8·87
11 × 3½ × 3½	·475	·575	·575	·400	29·82	8·77
11 × 4 × 4	·500	·600	·600	·425	33·22	9·77
12 × 3½ × 3½	·375	·500	·500	·350	26·10	7·67
12 × 3½ × 3½	·500	·600	·600	·425	39·88	9·67
12 × 4 × 4	·525	·625	·625	·425	36·47	10·73
15 × 4 × 4	·525	·630	·630	·440	41·94	12·33

BEAMS.

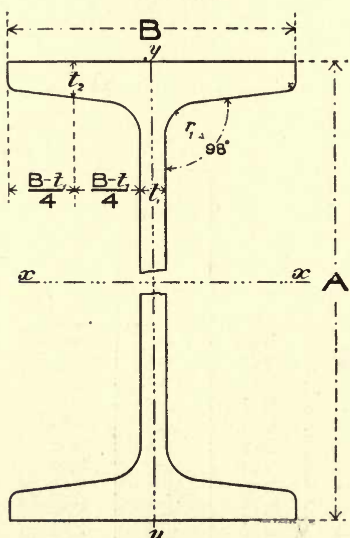


Fig. 167.

BEAMS—*continued.*

Reference Mark.	Size.	Weight per foot.	Thickness at Correct Standard Profile.		Radii.		Sectional area.
			Web.	Flange.	Root.	Toe.	
	A × B		t_1	t_2	r_1	r_2	
	in.	lbs.	in.	in.	in.	in.	in.
B.S.B. 1	3 × 1½	4	·160	·248	·260	·130	1·176
B.S.B. 2	3 × 3	8·5	·200	·332	·300	·150	2·501
B.S.B. 3	4 × 1¾	5	·170	·240	·270	·135	1·472
B.S.B. 4	4 × 3	9·5	·220	·336	·320	·160	2·795
B.S.B. 5	4¾ × 1¾	6·5	·180	·325	·280	·140	1·912
B.S.B. 6	5 × 3	11	·220	·376	·320	·160	3·238
B.S.B. 7	5 × 4½	18	·290	·448	·390	·195	5·290
B.S.B. 8	6 × 3	12	·260	·348	·360	·180	3·527
B.S.B. 9	6 × 4½	20	·370	·431	·470	·235	5·882
B.S.B. 10	6 × 5	25	·410	·520	·510	·255	7·354
B.S.B. 11	7 × 4	16	·250	·387	·350	·175	4·709
B.S.B. 12	8 × 4	18	·280	·402	·580	·190	5·297
B.S.B. 13	8 × 5	28	·350	·575	·450	·225	8·241
B.S.B. 14	8 × 6	35	·440	·597	·540	·270	10·293
B.S.B. 15	9 × 4	21	·300	·460	·400	·200	6·178
B.S.B. 16	9 × 7	58	·550	·924	·650	·325	17·064
B.S.B. 17	10 × 5	30	·360	·552	·460	·230	8·820
B.S.B. 18	10 × 6	42	·400	·736	·500	·250	12·358
B.S.B. 19	10 × 8	70	·600	·970	·700	·350	20·582
B.S.B. 20	12 × 5	32	·350	·550	·450	·225	9·408
B.S.B. 21	12 × 6	44	·400	·717	·500	·250	12·946
B.S.B. 22	12 × 6	54	·500	·883	·600	·300	15·879
B.S.B. 23	14 × 6	46	·400	·698	·500	·250	13·533
B.S.B. 24	14 × 6	57	·500	·873	·600	·300	16·769
B.S.B. 25	15 × 5	42	·420	·647	·520	·260	12·351
B.S.B. 26	15 × 6	59	·500	·880	·600	·300	17·346
B.S.B. 27	16 × 6	62	·550	·847	·650	·325	18·227
B.S.B. 28	18 × 7	75	·550	·928	·650	·325	22·066
B.S.B. 29	20 × 7½	89	·600	1·010	·700	·350	26·164
B.S.B. 30	24 × 7½	100	·600	1·070	·700	·350	29·392

T BARS.

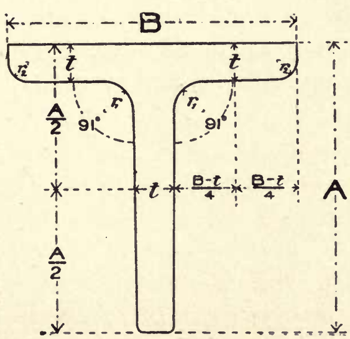


Fig. 168.

T BARS—*continued.*

Flange.	Web.	Thickness at Correct Standard Profile.			Radii.		Weight per foot.		Sectional area.	
					Root.	Toe.	Min.	Max.	Min.	Max.
B	A	t	t	t	r_1	r_2				
in.	in.	in.	in.	in.	in.	in.	lbs.	lbs.	in.	in.
1	1	·125	·187	...	·175	·125	·82	1·17	·24	·34
1¼	1¼	·125	·187	...	·200	·150	1·03	1·49	·30	·44
1½	1½	·187	·250	...	·200	·150	1·81	2·35	·53	·69
1¾	1¾	·187	·250	...	·225	·150	2·14	2·79	·63	·82
1½	2	·250	·312	...	·225	·150	2·79	3·40	·82	1·00
2	2	·250	·312	·375	·250	·175	3·22	4·64	·95	1·37
2¼	2¼	·250	·312	·375	·250	·175	3·64	5·28	1·07	1·55
2½	2½	·250	·312	·375	·275	·200	4·07	5·92	1·20	1·74
3	2	·312	·375	...	·275	·200	5·01	5·93	1·47	1·74
3	2½	·312	·375	...	·275	·200	5·53	6·56	1·63	1·92
3	3	·312	·375	·437	·300	·200	6·08	8·30	1·79	2·44
3	4	·375	·500	...	·325	·225	8·48	11·07	2·49	3·26
3½	3½	·375	·437	·500	·325	·225	8·49	11·08	2·50	3·26
4	3	·375	·500	...	·325	·225	8·49	11·08	2·50	3·26
4	4	·375	·500	...	·350	·250	9·77	12·78	2·87	3·75
4	5	·375	·500	...	·400	·275	11·09	14·50	3·25	4·26
5	3	·375	·500	...	·350	·250	9·78	12·79	2·87	3·76
5	3½	·500	...	...	·375	·250	13·66	...	4·02	...
5	4	·500	...	...	·400	·275	14·51	...	4·27	...
6	3	·375	·500	...	·400	·275	11·08	14·53	3·26	4·27
6	4	·500	...	...	·425	·300	16·22	...	4·77	...
7	3½	·500	...	...	·425	·300	17·08	...	5·02	...

The DIFFERDANGE BEAMS made by Messrs. H. J. Skelton & Co. are for many purposes better than those of the standard section. They are shallow, with broad flanges, most useful where the depth is restricted, while they can often be used where built-up girders are generally employed—and they are made of extraordinary length, the smaller sections up to 82 ft., and even the largest to 49 ft.

Chapter XXXIII.

COPPER.

NATIVE COPPER is found in large masses about Lake Superior, and in veins, distributed in crystalline form through granites and other rocks, in Cornwall. There are also many forms of copper ore, including the red oxide, known as cuprite (Cu_2O) ; the black oxide (CuO) ; and copper gravel (the sulphide, Cu_2S), all found in Cornwall; and the carbonates: malachite $CuCO_3 . Cu(OH)_2$, and azurite, $2CuCO_3 . Cu(OH)_2$, found at Burra-Burra, in Australia. The most abundant copper ores, however, are the pyrites, which when pure have the composition $Cu_2S . Fe_2S_3$, though they are usually associated with gangue and arsenic and with an excess of sulphide of iron.

The methods of reduction are numerous and complex, the three principal being the Dry Welsh Process, in which reverberatory furnaces of different forms are used for calcining and melting the ore alternately several times; the Wet Process, in which the copper is chemically dissolved from its sulphide ores; and the Electrolytic Process.

Of these the Welsh process alone need be described in detail. Several cargoes of ore are successively deposited in one large heap, and the heap is cut away in vertical slices so as to mix the ores. This mixture is first calcined and so reduced to a black powdery form, and then melted in a reverberatory furnace (see Fig. 169), so constructed that while a great heat is generated, beating down from the arched roof upon the dish of ore, the fuel and the ore do not mix, but the flame and smoke from the fuel pass

over the ore to the chimney. As the ore melts, the metallic portion drops to the bottom of the dish, and a lighter scum of slag rises to the surface. This is skimmed off with an iron rabble through the door, and its place taken by fresh

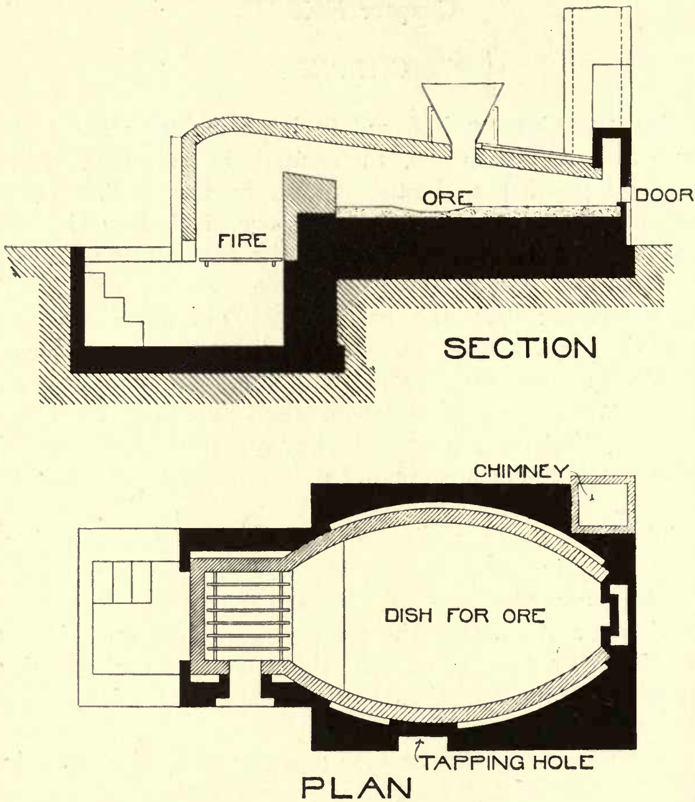


Fig. 169. Reverberatory Furnace.

calcined ore, and the skimming and filling repeated till the dish is full of metal only, which is then run out through the tapping hole into water and so granulated.

The whole process of calcining, melting, skimming and granulating has to be repeated three times before a product

containing even so much as from 80 to 90 per cent. of copper is obtained, and this is then cast into pigs instead of being granulated. The pigs are again melted, or roasted, under a strong current of air, and again cast into pigs, which are of honeycomb structure internally and covered outside with black blisters.

This "blister copper" is refined by re-melting, or refining, under a gradually increasing temperature, and the final slag skimmed off. The surface is then covered with charcoal, and a pole, usually of birch, is held in the liquid matter, causing considerable ebullition; and this poling is continued, with the addition of fresh charcoal so as to keep the surface covered, until by the assays which are taken from time to time it is found that the grain, which at the commencement of the operation was open, has quite closed, so as to assume a silky, polished appearance in the assays when half cut through and broken. The malleability is then tested by taking out a small quantity in a ladle, pouring it into an iron mould, and when set, and still hot, beating it out flat on an anvil. If it stands this without cracking at the edges, the metal is sufficiently toughened, and may be ladled out in clay-lined ladles and poured into moulds.

The reddish-brown sonorous metal thus produced is extremely soft and malleable and considerably ductile, with a specific gravity of about 8·78 and an ultimate tensile strength of about 7 tons per square inch.

Castings are rarely made from pure copper, owing to its extreme softness, but this is corrected by alloying it with zinc or tin (see Chapter on "Alloys").

When hammered and rolled, copper becomes rigid, stiff and hard, and even liable to crack and disintegrate, the change being purely mechanical. The specific gravity increases up to 9·0 and the tensile strength to 15 tons per square inch; while copper wire, $\frac{1}{10}$th of an inch in diameter, may be worked up to such a condition that it will require a strain of 300 lbs. to pull it asunder.

On exposure to the atmosphere, a protective film of so-called verdigris, a basic carbonate of copper of a green colour,* forms upon the surface, rendering the metal practically indestructible. On this account it is extensively used for masonry dowels; and, when the first cost is not prohibitive, for glazing bars. It is also used for lightning conductors, being an excellent conductor of electricity, and hot-water piping, geysers, baths and ventilators; but should be avoided in connection with drinking water, as the verdigris coating just mentioned is highly poisonous.

Sheet copper is one of the best roofing materials known, being very light, absolutely impervious, and practically everlasting, capable of being laid flat, as in flats and gutters, or of being worked to any curve, and developing a beautiful colour. The general stock size of sheets is 4 ft. by 2 ft., the Scotch size being 4 ft. by 3 ft. 6 ins.; but Messrs. Ewart & Son make sheets 5 ft. 3 ins. by 2 ft. 8 ins., specially for roofing purposes. The thickness known as 24 B. W. G., weighing 16 ozs. per foot super, is almost invariably used, for though thinner metal would generally suffice, it is more costly to roll, and anything thicker would be extravagant.

Larger sheets are obtainable without extra cost (by weight), but they have to be thicker. Up to 16 ft. superficial area they must weigh at least 28 ozs. per ft. super (20 B. W. G.); above this up to 24 ft. super they must weigh 32 ozs. (19 B. W. G.); and above this up to 28 ft. super they must weigh 48 ozs. per ft. (16 B. W. G.).

Hardened copper sheeting has of late been introduced by Messrs. Ewart & Son for rain-water eaves, gutters and ornamental features, such as finials, as being capable of standing with little or no support.

Copper wire is used for electric lighting, electric bells, and for ordinary bell-hanging—this last from 17 to 19 B. W. G., well stretched before use.

* This is not a true verdigris, which is a basic acetate of copper.

Chapter XXXIV.

LEAD.

LITTLE lead ore is now found in England, though at one time lead mining was an extensive industry in the North of England, Derbyshire, Wales, and Scotland. Most of the metal now in use is obtained as a bye-product of silver mining, as at the Broken Hill Mines in Australia, while a good deal is also obtained in the United States, Spain, the Hartz district of Germany, and Peru. The ore is mechanically separated out from the gangue, or spar with which it is mingled, and then roasted and reduced in a cupola or blast furnace. The principal ore is galena (the sulphide, PbS) ; though cerussite (the carbonate, $PbCO_3$) is extensively worked at Leadville, Colorado ; and anglesite (lead sulphate, $PbSO_4$) is occasionally found, especially in combination with silver.

Crude lead thus obtained needs refining before it is ready for use, but the following analyses show that after refining it becomes almost absolutely pure :—

	Freiburg Crude Lead. Per cent.	Commercial Lead. Per cent.
Lead	97·72	99·9837
Arsenic	1·36	
Antimony	0·72	0·0037
Iron	0·07	0·0016
Copper	0·25	0·0014
Silver	0·59	0·0080

Lead is one of the heaviest substances known, having a specific gravity of 11·35. It has a low melting point (617° Fahr.), and is soft and easily bent and worked or

beaten out to any desired form; but it is by no means ductile, and is greatly wanting in strength, being easily crushed, torn, and twisted. At the same time it well resists wear, and is practically impervious to water.

This last quality, together with its pliability, renders it a

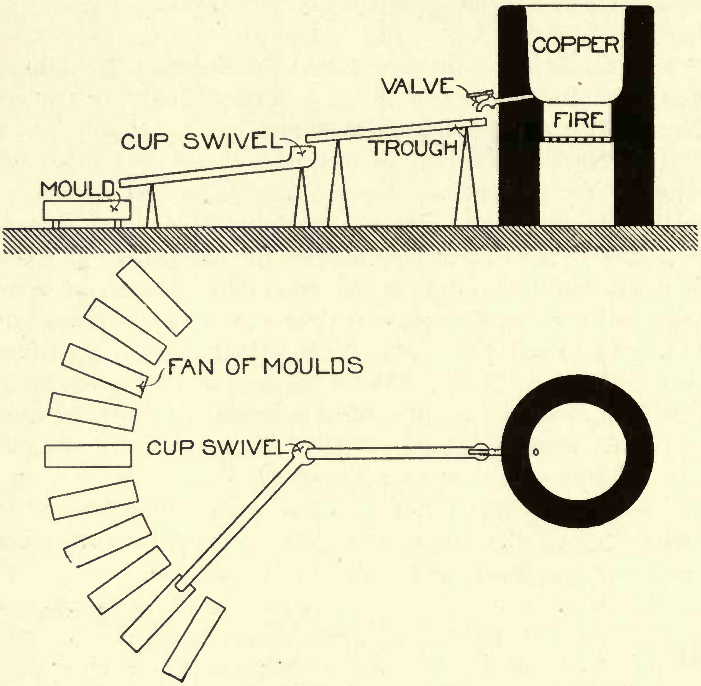


Fig. 170. Lead Melting Furnace.

most valuable material for use in water-carrying pipes, and for lining cisterns and sinks, while, used horizontally, it is one of the best roofing materials, as only just enough fall need be given to enable the water to flow towards the gutter or outlet and to compensate for accidental irregularities in the laying—a fall of 1 in 120, or 1 in. in 10 ft., being usually considered sufficient. Where good work is

required it is similarly used, almost universally, in gutters behind parapets and between roofs, in roof valleys, and as apron flashings.

Its low melting point, combined with its impermeability, has caused lead to be largely used in a molten state for making joints in iron pipes, and for "running in" iron cramps and the joints of iron railings to stonework; but not with success except under cover, as in the presence of moisture, and particularly in that of soft rain water, galvanic action is set up between the lead and iron, resulting in the destruction of both metals.

The lead as received from abroad is melted in a large copper pan with a furnace beneath it, similar to the ordinary domestic copper, only larger in size, and supplied with a valve near the bottom for letting out the molten metal. From this valve it is conveyed to any spot desired in semicircular troughs, the arrangement when running it into moulds being somewhat as is shown in Fig. 170. The moulds, which contain 1 cwt. of metal each, and are semicircular in section, are arranged in fan form round the furnace, and the lead is poured into each in rotation, any scum due to the metal becoming chilled being carefully removed and returned to the furnace.

Chilled lead, though pure, is brittle and of little value, so that its use must be avoided.

Sheet lead is generally made by casting a plate of lead about 5 ins. thick, weighing about 7 tons, and then passing this under metal rollers until it is squeezed down to the required thickness. Such sheets are known as "milled lead," and can be gauged very accurately, the various thicknesses being known by the weight in pounds per foot super. Such sheets are commonly made in lengths up to 35 ft., and in widths which vary from 5 ft. 6 ins. to 8 ft., but greater lengths and widths can be obtained if desired.

Sheets can also be made by pouring the molten metal on to a carefully levelled bed of sand on a wooden bench, and then passing a "strike" over the surface to sweep away

any surplus beyond the desired thickness. Such sheets are known as "cast lead," and they are generally thicker than the milled sheets and smaller in size.

Many architects, however, prefer cast lead, holding that the natural structure of the metal is broken up in the passage through the rollers, and that milled lead is thus rendered brittle and liable to crack if exposed to changes of temperature, as is inevitable upon roofs.

Gauges are procurable for testing the thickness of lead sheets according to the weight specified; but if any doubt exists it is best to cut off a rectangular piece from a sheet and weight it carefully, computing from that the weight of a square foot. In general practice, 4 or 5 lbs. lead is specified for aprons and flashings; from 6 to 8 lbs. for roofs, flats, and gutters; and from 5 to 7 lbs. for ridges and hips; but in exposed situations or on flats liable to wear these thicknesses are hardly sufficient.

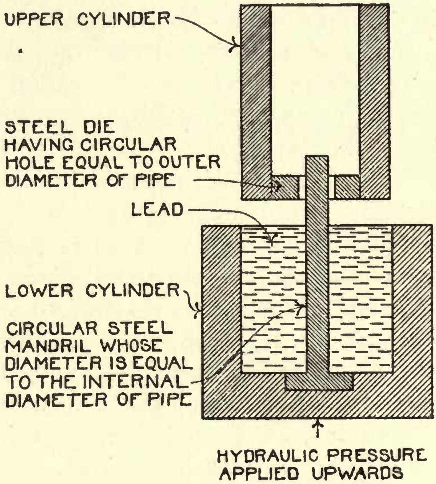


Fig. 171. Diagram of Pipe-making Press.

A very thin sheet is also rolled, known as "laminated lead," which is used as a lining to damp walls underneath the paper.

Lead pipes are made (at the works of Messrs. T. & W. Farmiloe) in a hydraulic press in a manner shown diagrammatically in Fig. 171. There are two steel cylinders, of which the upper is fixed while the lower is gradually lifted by hydraulic pressure, the lower one exactly enclosing the

upper. In the upper cylinder a steel die is fixed, having a circular opening, whose diameter is exactly equal to the desired outer diameter of the pipe ; while a steel mandril is fixed in the lower cylinder, whose diameter is equal to that of the inside of the pipe.

Molten lead is poured into the lower cylinder till it overflows, when the chilled scum is removed, and the metal allowed to partially cool. The hydraulic pressure is then applied to the lower cylinder, which rises, exactly encloses the upper cylinder, and forces the lead upwards between the mandril and the die.

Large pipes—that is, pipes of 2 ins. internal diameter and more—are helped to rise vertically, and are generally cut off in lengths of 10 ft. Pipes from 1 to 2 ins. in diameter are rolled in coils of 36 ft. long, containing three "lengths" of 12 ft. each ; while the coils of all smaller pipes than this contain four "lengths" of 15 ft. each, or a total of 60 ft. The weight in pounds per "length" is stamped at each end of each coil.

All the smaller pipes should be made of perfectly pure, new and unchilled lead, that they may bend readily as desired without cracking ; but large pipes, like soil pipes, require to have more stiffness, and this is imparted by mixing some old lead with the new.

Table of lead pipes manufactured by Messrs. T. and W. Farmiloe, Limited :—

LEAD PIPE.

$\frac{1}{4}$ in.	10	15	20	25	...	...	...	...	...	...	...	...	lbs. per 15 ft.
Equal to	2	3	4	5	...	...	...	...	...	...	...	...	lbs. per yard
$\frac{3}{8}$ in.	10	15	20	25	30	...	...	...	...	...	...	...	lbs. per 15 ft.
Equal to	2	3	4	5	6	...	...	...	...	...	...	...	lbs. per yard
$\frac{1}{2}$ in.	15	18	20	22	25	28	30	35	40	45	...	...	lbs. per 15 ft.
Equal to	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	7	8	9	...	...	lbs. per yard
$\frac{9}{16}$ in.	16	18	22	...	...	...	...	...	...	...	...	...	lbs. per 15 ft.
Equal to	$3\frac{1}{4}$	$3\frac{1}{2}$	$4\frac{1}{2}$	...	...	...	...	...	...	...	...	...	lbs. per yard
$\frac{5}{8}$ in.	18	22	27	30	35	40	45	...	...	...	...	...	lbs. per 15 ft.
Equal to	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$	6	7	8	9	...	...	...	...	...	lbs. per yard
$\frac{3}{4}$ in.	22	24	26	28	32	36	40	45	50	55	60	...	lbs. per 15 ft.
Equal to	$4\frac{1}{2}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$6\frac{1}{2}$	$7\frac{1}{4}$	8	9	10	11	12	...	lbs. per yard
1 in.	28	36	42	45	48	52	56	60	64	70	80	...	lbs. per 15 ft.
Equal to	$5\frac{1}{2}$	$7\frac{1}{4}$	$8\frac{1}{2}$	9	$9\frac{1}{2}$	$10\frac{1}{2}$	$11\frac{1}{4}$	12	13	14	16	...	lbs. per yard

In 15-ft. lengths, or 60 ft. coils.

LEAD PIPE—*continued.*

1¼ in.	28	32	36	42	48	52	56	60	64	72	80	88	lbs. per 12 ft.	In 12 ft. lengths, or 36 ft. coils.
Equal to	7	8	9	10½	12	13	14	15	16	18	20	22	lbs. per yard	
1½ in.	36*	42	48	56	63	72	84	96	...	...	...	...	lbs. per 12 ft.	
Equal to	9*	10½	12	14	15¾	18	21	24	...	...	...	...	lbs. per yard	
1¾ in.	56*	70	84	96	112	...	...	...	...	...	...	...	lbs. per 12 ft.	
Equal to	14*	17½	21	24	28	...	...	...	...	...	...	...	lbs. per yard	
2 in.	48*	56*	64*	72	84	96	112	120*	...	...	...	...	lbs. per 12 ft.	
Equal to	12*	14*	16*	18	21	24	28	30*	...	...	...	...	lbs. per yard	

Marked thus (*) in 12 ft. lengths only.

LEAD BARREL.

2¼ in.	96	...	...	...	...	lbs. per 10 ft.	In 10 ft. lengths.
Equal to	29	...	...	...	...	lbs. per yard	
2½ in.	85	96	120	...	...	lbs. per 10 ft.	
Equal to	25½	29	36	...	...	lbs. per yard	
3 in.	116	134	150	...	...	lbs. per 10 ft.	
Equal to	35	40	45	...	...	lbs. per yard	
3½ in.	135	156	166	175	...	lbs. per 10 ft.	
Equal to	40½	47	50	52½	...	lbs. per yard	
4 in.	156	166	184	196	250	lbs. per 10 ft.	
Equal to	47	50	55	59	75	lbs. per yard	
4½ in.	200	250	...	...	...	lbs. per 10 ft.	
Equal to	60	75	...	...	...	lbs. per yard	
5 in.	254	280	...	...	...	lbs. per 10 ft.	
Equal to	76	84	...	...	...	lbs. per yard	
6 in.	200	267	330	...	...	lbs. per 10 ft.	
Equal to	6	80	99	...	...	lbs. per yard	

RECTANGULAR LEAD SOIL PIPE.

4 in. × 3 in., equal to 8 lbs. lead
5 in. × 4 in., ,, ,,
in 12 ft. lengths.

LEAD SOIL PIPE.

Equal to	5	6	7	8	9	10	lbs. Sheet Lead.	
2 in.	...	40	...	...	...	...	lbs. per 12 ft., in 12 ft. lengths.	
2½ ,,	34	41	48	55	...	...	lbs. per 10 ft.	In 10 ft. lengths.
3 ,,	41	49	57	66	74	82	,, ,,	
3½ ,,	47	57	67	76	86	95	,, ,,	
4 ,,	54	65	76	87	98	109	,, ,,	
4½ ,,	...	73	85	97	...	...	,, ,,	
5 ,,	...	81	94	107	...	...	,, ,,	
6 ,,	...	...	...	128	...	...	,, ,,	

LEAD SOIL PIPE.

(As specified by the London County Council.)

3½ in. ... 65 lbs. per 10 ft. length.
4 ,, ... 74 lbs. ,, ,,

5 in. ... 92 lbs. per 10 ft. length.
6 ,, ... 110 lbs. ,, ,,

Chapter XXXV.

ZINC—GALVANIZED IRON.

THE principal zinc ores are those known as the calamine (the carbonate, $ZnCO_3$), zinc-blende or black-jack (the sulphide, ZnS), and the red oxide (ZnO). These are mostly found in the Ardennes, the Rhine country, Silesia, Greece, France, and the United States, the best known zinc-works being those of the Veille-Montagne Company of Liège, whose English agents are Messrs. Braby & Co.

The ore is reduced by roasting, mixing with half its weight of coke or non-caking coal, and then heating in retorts, the metal being driven out as a vapour, condensed, and then refined by melting on a hearth provided at one point with a well, into which any contained lead (generally from 1 to 3 per cent.) settles out in the course of two or three days.

The metal thus produced is brittle and fusible ; but it becomes malleable at about 220° Fahr., and at that temperature can be rolled into sheets which retain their malleability—though at a higher temperature, about 400° Fahr., this malleability is again lost. Its melting point is 774° Fahr., and it has a specific gravity of 7.

On exposure to the atmosphere a protective film of zinc oxide is soon formed on the surface ; but unfortunately this has not the permanent protective effect that verdigris has upon copper, especially near the sea and in large towns, as sea salt and acids act harmfully and soon destroy the metal. Soot and urine are also destructive to it, and consequently zinc should not be used in positions accessible to cats.

It is important that zinc should be pure—when it is of

uniform colour (dull grey), tough, and easily bent without cracking; while if impure, it is darker in tone and blotchy in appearance. If it contain iron to any perceptible extent it will not resist the action of the air, while the presence of lead makes it too brittle to roll.

The following analysis of Veille-Montagne zinc shows that it is practically pure:—

Pure zinc	99·5
Traces of iron	0·4
Lead and sulphuret	0·1
	100·0

Sheet zinc is largely used for flat roofs, gutters, and flashings, and is supposed to have a life of about twenty years under ordinary London suburban conditions. It is also stamped into ornamental tiles, ridge cresting, and eaves gutters, and is even used for rain-water pipes; but its brittleness and want of stiffness prevent its being of much value if so employed. As a lining to drinking-water cisterns it is satisfactory, but its greatest value is as a protective coat to ironwork (see Galvanizing), and as a component of alloys.

If zinc be allowed to come in contact with iron, copper, or lead in the presence of moisture, galvanic action is set up, and the zinc is rapidly destroyed. It catches fire at a low temperature, and blazes furiously.

The expansion and contraction of zinc under changes of temperature are considerable, being more than those of other metals, not excepting lead, and must be carefully provided for by avoidance of rigid fastenings.

Zinc is rolled in sheets of 6, 7 or 8 ft. long by 3 ft. wide; though longer sheets up to a maximum length of 10 ft. are obtainable by extra payment. The thicknesses are standardised by a special zinc gauge, by which they should always be specified. For roofing purposes, 14, 15, and 16

gauges are those mostly used, but 14-gauge zinc is really too thin to be reliable. Thinner gauges than this are mostly used in perforated sheets for ventilation purposes, and the thicker gauges are stamped into eaves gutters, ornamental tiles, etc.

ZINC GAUGE.

List of Weights and Thicknesses.

Gauge.	Approximate Thickness.		Approximate weight per square foot.			Approximate weight of Sheets.								
						36 in. × 72 in.			36 in. × 84 in.			36 in. × 96 in.		
	Thousandths of an Inch.	Metric Equivalent in Thousandths of a Millimètre.	lbs.	ounces.	drachms.	lbs.	ounces.	drachms.	lbs.	ounces.	drachms.	lbs.	ounces.	drachms.
1	0·004	0·100	...	2	5	Nos. 1 and 2 are only rolled to order and special dimensions.								
2	0·006	0·141	...	3	4									
3	0·007	0·171	...	3	15	4	6	14	5	2	11	5	14	8
4	0·008	0·209	...	4	13	5	6	10	6	5	1	7	3	8
5	0·010	0·247	...	5	11	6	6	6	7	7	7	8	8	8
6	0·011	0·291	...	6	11	7	8	6	8	12	7	10	0	8
7	0·013	0·337	...	7	12	8	11	8	10	2	12	12	10	0
8	0·015	0·386	...	8	14	9	15	12	11	10	6	13	5	0
9	0·018	0·450	...	10	5	11	9	10	13	8	9	15	7	8
10	0·020	0·500	...	11	7	12	13	14	15	0	3	17	2	8
11	0·023	0·580	...	13	5	14	15	10	17	7	9	19	15	8
12	0·026	0·660	...	15	2	17	0	4	19	13	10	22	11	0
13	0·029	0·740	1	0	15	19	0	14	22	3	11	25	6	8
14	0·032	0·820	1	2	12	21	1	8	24	9	12	28	2	0
15	0·038	0·950	1	5	12	24	7	8	28	8	12	32	10	0
16	0·043	1·080	1	8	12	27	13	8	32	7	12	37	2	0
17	0·048	1·210	1	11	11	31	2	6	36	5	7	41	8	8
18	0·053	1·340	1	14	11	34	8	6	40	4	7	46	0	8
19	0·058	1·470	2	1	11	37	14	6	44	3	7	50	8	8
20	0·063	1·600	2	4	10	41	3	4	48	1	2	54	15	0
21	0·070	1·780	2	8	12	45	13	8	53	7	12	61	2	0
22	0·077	1·960	2	12	14	50	7	12	58	14	6	67	5	0
23	0·084	2·140	3	1	1	55	3	2	64	6	5	73	9	8
24	0·091	2·320	3	5	3	59	13	6	69	12	15	79	12	8
25	0·098	2·500	3	9	5	64	7	10	75	3	9	85	15	8
26	0·105	2·680	3	13	7	69	1	14	80	10	3	92	2	8

Note.—It is impossible to roll sheets exactly to any given weight or thickness, and therefore a slight deviation must be allowed.

GALVANIZED IRON.

An important use of zinc is as a preservative coating to ironwork, known as Galvanizing. The iron is first "pickled" in dilute acid to remove all rust and cleanse it

thoroughly, and is then heated and immersed in molten zinc, which is covered with a layer of sal-ammoniac to keep it from evaporating. When withdrawn, a film of zinc is found to have adhered to the iron, which it preserves against rust so long as the film remains intact—which it will do for some years if exposed only to rain and moderate wear, though it is soon penetrated in an acid or salt-burdened atmosphere, as also is sheet zinc.

The articles most commonly galvanized are rain-water pipes, down pipes, manhole covers, and corrugated rolled sheets for roofing. These last are largely used, and should be corrugated before they are galvanized, else there is liability of the zinc being cracked during the process of corrugating. If this occurs, moisture entering the crack completes the galvanic connection between the two metals (iron and zinc), and both are then rapidly destroyed.

CORRUGATED IRON ROOFING.

B. W. G.	Size of Sheet.	Weight per Square.			Sq. ft. p. ton.
		cwts.	qrs.	lbs.	
No. 16	6 ft. × 2 ft. to 8 ft. × 3 ft.	3	0	14	800
" 18	" " "	2	1	6	1000
" 20	" " "	1	3	6	1250
" 22	" " 7 ft. × 2 ft. 6 in.	1	2	7	1550
" 24	" " "	1	0	24	1880
" 26	" " "	1	0	6	2170

The Sheets should have 6-in. Laps, and be Double-rivetted at Joints: 3 lbs of rivets required per Square.

Hot galvanizing, as described above, is the process most extensively used to apply a zinc coating to iron and steel. Electro-zincing, or cold galvanizing, is used for special classes of work. A third method, called Sherardizing, has now been developed, and works have recently been completed for carrying it out on a commercial scale. By this new process iron and steel can be coated with a thin even deposit of zinc at a temperature below the melting point of this metal. The first step in the process is to free the

iron from scale and oxide by any of the well-known methods, such as dipping in an acid solution or sand-blasting. The articles to be rendered rust-proof are then placed in a closed air-tight iron receptacle (exhausted of air to prevent oxidization of the zinc) charged with zinc dust, which is heated to a temperature of from 500° Fahr. to 600° Fahr. for a few hours and allowed to cool. The drum is then opened and the iron articles are removed, when they are found to be coated with a fine homogeneous covering of zinc, the thickness depending on the temperature and the length of treatment. The temperature required to bring about this result is about 200° below the melting point of zinc. The low temperature required makes the process cheap as compared with the process of dipping in molten zinc, and has the additional advantage that it does not deteriorate iron or steel of small section to the same extent as hot galvanizing. The whole of the zinc is consumed, and there is no waste of zinc as in the hot galvanizing process. This dry process of coating iron is not limited to zinc, but has been applied to coating iron with copper, aluminium, and antimony, and to coating other metals, such as aluminium and copper, with zinc. Copper and its alloys subjected to this process are case-hardened on the surface, and can be rendered so hard as to turn the edge of a steel tool. The zinc powder used is the zinc dust of commerce, and is obtained during the process of distilling zinc from its ores. One of its peculiar properties is that it cannot be smelted or reduced to the metallic form under ordinary conditions even when heated to a very high temperature under considerable pressure, and this is advantageous in the new process of galvanizing, as it does away with the risk there might be otherwise of melting the finely divided zinc through overheating of the furnace.

Chapter XXXVI.

ALLOYS: BRASS AND BRONZE—PEWTER AND COMPOSITION.

INTIMATE mixtures, or solid solutions, of metals, made by melting them together, are known as ALLOYS—possessing properties which differ widely from those of the metals of which they are composed, and varying in a strange and apparently erratic fashion, according to the proportions of the various mixtures.

The most important alloys are those of which copper is the basis—Brass, Bronze, Gunmetal, and a few others slightly differing from these to which special names have been given. They are much used for small cast objects, such as taps, door handles, hinges, and minor fastenings of all kinds, while those of harder character are employed for the bearings of machinery.

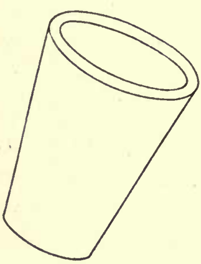


Fig. 172. Plumbago Crucible.

All are prepared similarly. The metals of which they are composed are melted in crucibles or pots, generally made of plumbago (see Fig. 172), the less fusible metal being melted first, and those with lower melting points added afterwards in rotation. The crucibles are plunged into the heart of the furnace, each lasting for about three meltings, and the contents when incorporated are cast into ingots. These are remelted in the same way, a little old metal being commonly added to assist in perfect incorporation when casting is to take place.

The objects to be made being small and in great demand, metal patterns are kept, with projections to represent the

ends of the cores, as shown in Fig. 173, which is an illustration of the pattern for an ordinary tap casing. The cores also are made in hinged metal moulds, of tightly packed loamy sand, slightly damp.

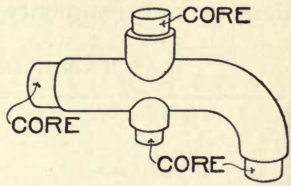


Fig. 173. Pattern of Tap.

As a rule several small objects are cast at once, but for the sake of clearness only one is shown in Fig. 174, which illustrates the "flasks" in which the castings are made. The lower "flask"—nothing else than a metal tray, about 4 ins. deep—is filled with sand with the pattern carefully inserted to half its depth. The pattern is withdrawn, the space it occupied dusted with dry sand, and it is replaced, when the dusting is repeated and carried over the whole surface of the lower flask. The upper flask, which has no top, is then dropped into place and packed with damp sand. When it is lifted it carries with it the sand it contains. The pattern can then be removed and the sand core placed in the sockets in the lower flask which were made for it by the pattern. The upper flask is then quietly replaced in position and the metal poured into the space formerly occupied by the pattern through carefully arranged holes, enclosing the core. When the metal cools, the sand is removed from the flasks and the casting taken out, the sand core dropping out when tapped. All that is needed is for the rough surface to be smoothed and polished.

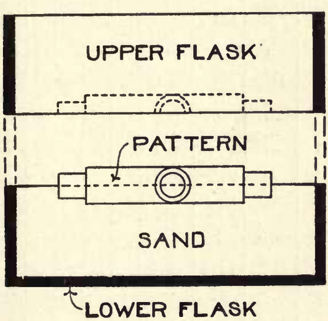


Fig. 174. Brass Casting: Arrangement of Flasks.

BRASS, though the name is often given to all copper

alloys promiscuously, properly means a mixture of copper and zinc, a little phosphorus being sometimes added to make it fusible. It is a tough alloy, its colour varying from a light to a reddish yellow, according to the proportions of its constituents, that containing more copper being

TABLE OF COPPER ALLOYS.

—		Constituents.								
		Copper.	Zinc.	Tin.	Lead.	Antimony.	Iron.	Manganese.	Bismuth.	Aluminium.
Name.	Purpose for which Used.	Proportions by Weight.								
Brass	Ordinary—for taps, etc. ...	2	1	—	—	—	—	—	—	—
,,	Locks and door handles ...	3	1	—	—	—	—	—	—	—
,,	Turning and fitting (can be filed but not hammered).	3	1	...	$\frac{1}{12}$	—	—	—	—	—
,,	Engraving name plates, etc.	3	1	A little	—	—	—	—	—	—
,,	Bushes and sockets	18	1	—	—	—	—	—	—	—
,,	Plumbers' unions (for soldering.	$2\frac{2}{3}$	1	—	—	—	—	—	—	—
Pot Metal	Common taps and inferior work.	$2\frac{1}{2}$	...	...	1	—	—	—	—	—
Bronze	Stop-cocks and valves ...	88	10	2	—	—	—	—	—	—
,,	Machinery bearings	8	...	1	—	—	—	—	—	—
,,	Small toothed wheels... ...	10	...	1	—	—	—	—	—	—
,,	Heavy bearings...	32	1	5	—	—	—	—	—	—
Manganese Bronze	White alloy, tough and strong as steel and resists corrosion.	88	...	10	...	...	...	2 to 30	—	—
Gun-Metal	Ordnance	$90\frac{1}{2}$	...	$9\frac{1}{2}$	—	—	—	—	—	—
,,	Turning	5	...	1	—	—	—	—	—	—
,,	Ornamental work	16	...	1	—	—	—	—	—	—
Bell Metal	Bells	4	...	1	—	—	—	—	—	—
Muntz Metal	Bearings and hinges { from / to	50 / 63	50 / 37	...	Less than $\frac{1}{100}$	—	—	—	—	—
Gedge's Metal	Bearing and hinges	60	38·2	...	...	...	1·8	—	—	—
Sterro Metal	In place of wrought iron ...	55 to 60	34 to 44	1 to 2	2 to 4	—	—	—	—	—
Babbit's Metal	Bearings, smooth and soft, and melts if bearings heat.	4	8	96	—	—	—	—	—	—
White Brass	Smooth bearings	3	...	90	...	7	—	—	—	—
,,	,, ,, ...	1	...	...	7	7	—	—	—	—
Expansive Metal	To expand in cooling... ...	...	...	...	90	2	...	...	1	—
Aluminium Bronze	Instruments—Very light and does not tarnish	90 to 95	...	...	...	...	...	...	...	10 to 5
Phosphor Bronze	Where toughness and wearing qualities are needed	Any copper alloy with the addition of a little phosphorus.								

the more red in tone; it is readily filed and cut; it casts easily, and can be easily burnished and kept brightly polished.

BRONZE is the name given to alloys of copper and tin. These metals are difficult to combine, as their melting points and specific gravities are very different. Consequently *Hard Metal* is first made by putting the tin into twice its weight of copper, afterwards adding the rest of the copper, separately melted. Large castings are often not homogeneous owing to the difficulty of obtaining perfect incorporation. Under the names of *Gun Metal* and of *Bell Metal*, given to bronze containing certain proportions of copper and tin, it is largely used for machinery bearings, hinges, stop-cocks, and wherever resistance to constant wear is required in combination with a colouring similar to that of brass though richer in tone, and the capacity of retaining a good polish; and it is also much used, as its name implies, for bells.

Several other copper alloys, mostly used for machinery bearings, are mentioned in the table on p. 322, but they are not much used in building work.

PEWTER is the name given to any alloy of lead and tin. It is mostly used in building works for covering the counters of public-houses, but the softer and heavier qualities, containing more than 20 per cent. of lead by weight, and having a specific gravity of more than 7·8, should not be used, as being liable to poison any liquid with which it may come in contact. Even then, however, it is not so dangerous as is sheet lead in a similar position.

A slightly harder pewter, containing less than 17 per cent. of lead, is occasionally used in ornamental panels. It can be either cast or stamped.

COMPOSITION, more generally known as COMPO., is made of lead, tin, and antimony. The harder qualities are used for slating nails, for which purpose compo. is well adapted, as it does not corrode readily, while it is cheaper than any alternative. Softer qualities are much used for inferior gas-piping, for which pure lead is unsuitable. Compo.

pipes have the advantage that they can be easily bent and soldered like lead pipes, but their soft nature renders them dangerous for use unless properly cased—especially when hidden beneath plaster—as they are readily penetrated by a nail.

COMPOSITION GAS PIPE.

$\frac{1}{8}$ in.	...	3 ozs. per yard.	$\frac{9}{16}$ in.	...	28 ozs. per yard.
$\frac{3}{16}$ in.	...	5 ozs. ,,	$\frac{5}{8}$ in.	...	46 ozs. ,,
$\frac{1}{4}$ in.	...	9 ozs. ,,	$\frac{3}{4}$ in.	...	$3\frac{1}{4}$ lbs. ,,
$\frac{5}{16}$ in.	...	13 ozs. ,,	$\frac{7}{8}$ in.	...	4 lbs. ,,
$\frac{3}{8}$ in.	...	17 ozs. ,,	1 in.	...	5 lbs. ,,
$\frac{7}{16}$ in.	...	21 ozs. ,,	$1\frac{1}{4}$ in.	...	$6\frac{1}{4}$ lbs. ,,
$\frac{1}{2}$ in.	...	26 ozs. ,,			

In coils about $\frac{1}{2}$ cwt. each.

BLOCK-TIN pipe is also made, but is costly, and therefore not much used, but the same thing encased in lead is employed a good deal for the drawpipes for beer in public-houses and for the necessarily strong piping employed in mineral water manufactories.

LEAD ENCASED BLOCK-TIN PIPE.

$\frac{1}{2}$ in.	...	$3\frac{1}{2}$ and $4\frac{1}{2}$ lbs. per yard.	$1\frac{1}{4}$ in.	...	10 and 12 lbs. per yard.
$\frac{9}{16}$ in.	...	$3\frac{1}{2}$ and $4\frac{1}{2}$ lbs. ,,	$1\frac{1}{2}$ in.	...	14 and 16 lbs. ,,
$\frac{5}{8}$ in.	...	$4\frac{1}{2}$ and $5\frac{1}{2}$ lbs. ,,	$1\frac{3}{4}$ in.	...	17 and 24 lbs. ,,
$\frac{3}{4}$ in.	...	$5\frac{1}{2}$, 7 and 8 lbs. ,,	2 in.	...	18 and 28 lbs. ,,
1 in.	...	7 and 10 lbs. ,,			

BLOCK-TIN PIPE.

$\frac{1}{4}$ in.	...	9 ozs. per yard.	$\frac{5}{8}$ in.	...	23 ozs. per yard.
$\frac{5}{16}$ in.	...	$11\frac{1}{2}$ ozs. ,,	$\frac{3}{4}$ in.	...	30 ozs. ,,
$\frac{3}{8}$ in.	...	13 ozs. ,,	$\frac{7}{8}$ in.	...	38 ozs. ,,
$\frac{7}{16}$ in.	...	14 ozs. ,,	1 in.	...	48 ozs. ,,
$\frac{1}{2}$ in.	...	17 ozs. ,,			

Chapter XXXVII.

PAINTS: BASES, VEHICLES, DRIERS, SOLVENTS — ADULTERANTS AND THEIR DETECTION — KNOTTING AND STOPPING —REMOVING OLD PAINT.

PAINT consists of at least two essential parts—the *Base*, or general substance, giving consistency and covering power, and the *Vehicle*, or semi-liquid, in which the base is incorporated to enable it to be spread in a thin and even coat by means of a brush. In addition to these essentials, most paint includes some *Drier* which will combine with the vehicle in the presence of air and tend to harden and dry it rapidly; some *Solvent*, or freely-flowing liquid, used for diluting the vehicle until it is thin enough to be applied freely; and some colouring *Pigment*, introduced for decorative purposes.

The characteristics of a good paint are that it should be liquid enough to be applied with a brush or spray; that it should dry within a reasonable time (say forty-eight hours); that it should adhere firmly to the surface to which it is applied; and that the dried surface should remain smooth, impervious, and moderately wear resisting.

BASES.

By far the most commonly used *Base*, in England at any rate, is white-lead, though its employment is forbidden in France on account of its poisonous qualities. Other bases, more or less used, are red-lead, zinc-white, barytes, ferric-oxide, lithopone (rare), and a few of the pigments such as the ochres, umbers, and Prussian blue.

Of these, WHITE-LEAD is a basic carbonate of the metal, sometimes supplied as a powder, but more often mixed with from 7 to 9 per cent. of linseed oil. Besides being used as a base for oil paint, it is frequently employed as a cement for the joints in iron pipes.

Though several other methods of manufacture have been tried, the Dutch stack process is almost universally used. The purest metallic lead is cast into the form of cross-bar grids (see Fig. 175), which are laid over pans containing weak vinegar or acetic acid and covered with spent tan, this being again covered with boards. On top of the boards the arrangement of pan, grids and tan is repeated, and so on until a tall stack is built up.

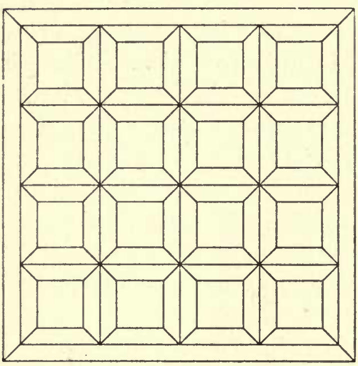


Fig. 175. Cross-bar Grids.

The chemical changes which take place do not seem to be very well understood, but apparently the acetic acid evaporates, converting the surface of the lead into basic acetate of lead. The tan heats, giving off CO_2, which combines with the acetate of lead to form a white basic carbonate of lead, that is, a carbonate of lead with excess of lead. In course of time the entire stack of lead is thus converted, and the grids are broken up and ground in water to a fine powder, and dried.

To bring this into the best condition for use by the painter, the powder is mixed with refined linseed oil, and, as seen at the works of Messrs. T. and W. Farmiloe, ground between horizontally revolving grindstones, until the pigment grain is entirely broken. The white-lead thus prepared is immediately packed in tins ready for use.

It is insoluble in water, but dissolves readily in dilute

nitric acid, and also, with effervescence, if heated in hydrochloric acid. Adulteration is therefore easily detected, by placing a little white-lead powder (after burning off the linseed oil) in a saucer and covering it with either of these acids, heating it over a gas flame if hydrochloric acid be used. Any insoluble residue will be an adulterant—probably sulphate of barium.

Pure English white-lead alone should be specified and used ; while that of which the pigment grain has been thoroughly broken by grinding in oil possesses more covering power, when used as a paint, than that which is imperfectly ground.

Unfortunately, white-lead is highly poisonous, both to those engaged in its manufacture and to painters who use it much. It also possesses the disadvantage of darkening considerably in impure air, and in the presence of sulphur in any form, and so cannot properly be used with some of the most beautiful pigments known, such as ultramarine for instance. It is also liable to change in composition. New dry white-lead has a different composition from that of the same sample after six, nine, or twelve months, and it changes still more when ground in oil.

RED-LEAD, or MINIUM, is the higher oxide of lead, obtained by raising the lower oxide, generally known as *Massicot*, to a high temperature in air, during which process it absorbs oxygen and becomes further oxidized. It is sold as a bright red powder, the colour of which is permanent so long as it does not come into contact with any preparation containing lead or acids mixed with it ; while in the presence of impure air it turns black.

It is used more as a drier than as a base, being mixed with white-lead paints to make them dry rapidly; but is sometimes mixed with oil and then used as the base of paint upon ironwork, and for making watertight joints in ironwork and between wood and iron. At times it is mixed with white-lead when so employed. It is also the

most frequently used base for the priming, or first coat upon woodwork.

Oxide of Zinc, or "Zinc White," as it is commonly called, is much more largely used as a base than is generally supposed, for it is employed in almost all the paints to which special trade names are given. It is a simple zinc oxide (ZnO) obtained by distilling metallic zinc under a current of air. The zinc vaporises under heat, and picking up oxygen from the air, condenses on cool plates in the form of an amorphous white powder, of similar appearance to snow. This is rolled in water under pressure to increase its opacity and covering power, and is then ready for use after being dried and again ground in oil; and its value greatly depends upon the skill and thoroughness with which this is done.

The principal advantages possessed by oxide of zinc are its pure white colour, which does not go off in the presence of sea air or of sulphur, the fact that it is non-poisonous, and its considerable covering power,—though this last is only possessed by the better and dearer qualities, it being often thinned down with oil to reduce its price so as to compare favourably, apparently, with that of white-lead, with the result that the covering power is greatly reduced and much more has to be used. On the other hand, fewer coats of oxide of zinc paint than of white-lead paint are necessary, each being of first-rate quality (as, for instance, the condensed snowball zinc of the Indestructible Paint Co., and Messrs. T. and W. Farmiloe's white-lead), so that when the initial additional cost of material in the one case is balanced against the extra cost of labour in the other, there is little or no eventual difference.

Oxide of zinc is practically without action on linseed oil. Therefore the drying of paint made from oxide of zinc is due entirely to the siccative nature of the oil itself in which the oxide of zinc may be considered as mechanically suspended; a state of things more readily under control than is the case with white-lead paints, in which the powerfully

siccative action of the hydrate portion of the white-lead often proceeds too far. The oil is then burnt up, so to speak, the paint perishes, and "chalking" results. The name of "zinc white" may also be correctly applied to another pigment—Sulphide Zinc White—which is the pigmentary base of much white paint now used.

BARYTES (sulphate of barium) is more frequently used as an adulterant or reducer of white-lead or zinc white than as a base in itself, for it possesses comparatively little covering power.

FERRIC-OXIDE (about 95 per cent. Fe_2O_3), produced from a brown hæmatite iron ore found in Devonshire, is sometimes used as a base for paint upon ironwork, especially for the first coat, there being a common belief that galvanic action is set up between lead or zinc paint and the metallic iron, which leads to its destruction. This is, of course, impossible so long as the skin of paint is intact, but may occur when it is broken and the galvanic couple completed by the presence of moisture.

"Pure Magnetic" oxide of iron, containing 95 per cent. sesqui-oxide of iron, prepared in chemically refined linseed oil, is a most valuable metal covering, but owing to the crystallization of oxide of iron, the first object of a good base is defeated, for it attacks the life of the oil. Oxide of iron does not combine with linseed oil at all, the process of drying depending alone on the absorption of oxygen by the oil, in which the pigment assists in a purely mechanical way.

The higher the percentage of sesqui-oxide of iron contained in the oxide the slower the paint is in drying.

Oxide of iron paints give very short protection to iron or steel in the presence of sea water.

VEHICLES.

Putting aside TUNG OIL, to which the Japanese owe much of their success in paint making, but the cost and

small production of which preclude its use in this country, there is practically only one vehicle in use for paint, and that is LINSEED OIL, made by compressing flax seed, the best being obtained from the Black Sea and the Baltic and an inferior quality from India. It should be absolutely pure, pressed from ripe seed and from flax which is cultivated for seed and not for fibre.

In its raw state, merely allowed to settle until it can be drawn off clear after being expressed, it is pale in colour, sweet to the taste, free from scent, and transparent, and is suitable for grinding up pigments and bases and for use in internal work where exposure to weather is unlikely. For delicate tints its use is imperative. It oxidizes, becoming hard and stiff upon exposure to air, but does not thicken greatly nor become opaque or greatly weather resisting. The oil should not be used less than six months old, and is better if kept for several years. It dries somewhat slowly, a thin film spread upon glass taking two or three days to dry, according to the state of the weather.

Oil pressed from unripe seed or flax which is raised entirely for the fibre yields on an average about 10 per cent. of water. It is from this character of flax that much of our "commercially pure linseed oil" is pressed. This must be treated—freed from water, glutinous substances known as muscovites, and other contaminations—before it can be used in preservative paint, where reliable and uniform results are expected.

BOILED OIL not only dries more quickly than does raw oil, but becomes more thick and weather resisting on exposure to the atmosphere. Other substances, such as red-lead, umber and litharge (a pound of each to a gallon of oil) are generally added to increase these properties, though the umber only acts as a pigment and is used merely to pander to a prejudice which exists for a dark oil. The oil in its raw state is raised to about 200° Fahr., and when it looks brown and the scum has all burnt off the red-lead, etc., are added, and the temperature then

increased to about 400° Fahr., which temperature is maintained for three or four hours. When the oil is drawn off, albuminous matter is deposited, leaving it clear but dark in colour. A thin film spread upon glass should dry in between twelve and twenty-four hours.

For use with a zinc base, boiled oil must be free from the lead oxides (red-lead and litharge). Peroxide of manganese is substituted, in the proportion of 5 per cent. of the oil by weight, and the mixture is boiled for five or six hours, and then allowed to cool, and eventually filtered.

When internal painting of delicate tints is required to dry quickly, a pale drying oil is used, having 7 lbs. of litharge or acetate of lead to the gallon of oil, raised to a moderate temperature only; while for common work a drying oil can be made by boiling $1\frac{1}{2}$ lbs. of red-lead in a gallon of oil.

POPPY OIL and NUT OIL have occasionally been employed as substitutes for linseed oil, but they are not durable and are little used.

DRIERS.

Not only are drying substances added to oil in the process of boiling, but they are frequently added also to cold oil (raw or boiled), and to mixed paint, for the same purpose. They apparently act as carriers of oxygen to the oil, and consequently the best are those which contain a considerable proportion of oxygen.

LITHARGE, or MASSICOT, is the drier most used for lead paints. It is an oxide of lead produced in extracting lead from its ores, or by heating metallic lead to an extent insufficient to fuse the oxide.

RED-LEAD, another oxide of lead, is also often used where its colour is no objection, but it is not so rapid in its action as is litharge.

ACETATE OF LEAD, also known as SUGAR OF LEAD, is sometimes used for light tints; while JAPANNERS' GOLD SIZE and VERDIGRIS (acetate of copper) are used for dark

colours—though an excess of the size must be avoided if it tends to make the paint brittle.

For use with zinc paints it is necessary to avoid lead compounds, and the best drier is found to be SULPHATE OF MANGANESE ($MgSO_4$), of which only 6 or 8 ozs. need be used per cwt. of ground zinc paint. The manganese should be first mixed with a small quantity of the paint and then added to the bulk, and great care must be taken in this, else the work will be spotted.

SULPHATE OF ZINC ($ZnSO_4$) serves the same purpose.

OXIDE OF MANGANESE is also used, and is quick in its effects, but it is dark in colour, and so can only be used for deep tints.

What are known as PATENT DRIERS are supplied ready mixed, composed of any of the above ingredients, and if obtained from a reputable firm are to be depended upon; but inferior qualities sometimes depend for their drying qualities upon lime, and in all cases the fact that the ingredients are not known may lead to their being used wrongly.

Driers should not be used unnecessarily—as, for instance, with pigments which themselves dry well, nor with special paints whose composition is unknown; nor should they be used in excess, the result frequently being to retard instead of accelerate drying. Not more than one drier should be added to the same colour, and none to finishing coats of light tint; and they should only be added just previously to use.

SOLVENTS.

SPIRITS OF TURPENTINE, generally known as TURPS, is the only substance used as a solvent for oil paints, and that not to a very great extent. It is obtained by distillation of the crude turpentine which exudes from pines and larches, the residuum being rosin. Turps, like linseed oil, oxidizes on exposure to air, and is converted into a resinous substance; but this has little of the weather-

resisting properties of oil, and should be only used, if at all, in external work to just a sufficient extent to make the paint flow readily from the brush. In internal work it is less needed for this purpose, as raw oil can be used ; but if a matt surface be desired, the last, or flatting, coat must be mixed with turps instead of oil, to avoid the slightly shiny effect of an oil paint.

Good turps should have a pleasant, pungent odour, whereas the odour of bad turps is disagreeable ; and it is colourless and inflammable, with a specific gravity of ·87, and a boiling point of 320° Fahr.

It is sometimes adulterated with mineral oil, which, being volatile, is valueless, and occasionally contains pyroligneous acid. It is better for being kept and allowed to settle for some time before use.

The test for adulteration is evaporation, which should leave practically no residue ; but it is rarely that a test is resorted to, and trust has to be placed in the reputation of the manufacturers. American turps is generally considered to be the best, and it is a testimonial to its qualities to find that of the recently introduced "Pinex" (itself a true oil of turpentine) no higher praise is attempted by its manufacturers than to say that it equals the American in all respects. In the following particulars it will be seen that they are practically identical :—

——	American Turps.	Pinex.
Specific gravity	·864 at 15° C.	·864 at 15° C.
Boiling point	156° to 168° C.	158° to 166° C.
Fraction boiling above 180° C. ...	1·5	1·7
Rotation	15 degrees.	15 degrees.

TURPENTINE is a solution of ROSIN in volatile oils; and Rosin is a degradation product of all fir timber, from which it exudes. Botanists say that it is produced by the breaking down of starch granules found in wood cells, and

by the disintegration of cell walls; while chemists call it an oxidation product of volatile oils.

The rosin for *American Turpentine* is obtained from all four varieties of the wood which we know in England as pitch-pine. A box-shaped cut is made in one side of the tree to hold about a quart of sap, and the tree is barked to a height of five feet, an incision being made running up in a V shape from the box, and cut deeply into the sapwood. Resinous matter exudes and collects in the box, whence it is taken for distillation into rosin and turpentine. The tree is thus bled for three years, and is then felled.

Russian Turpentine, mostly from *Pinus Sylvestris*, is not obtained by bleeding, but by cutting stumps and dried roots into strips and throwing these into boilers with much water, the turpentine being distilled through a worm.

French Turpentine is similarly obtained from the *Pinus Pinaster.*

CANADA BALSAM is a turpentine obtained from the Canadian *Abies Balsamea.* Thinned with *turpentine* it makes a good transparent varnish on paper, over three coats of isinglass size.

The gums MASTIC and SANDARAC are similar degradation substances to rosin, found in other trees; and so also is indiarubber.

ADULTERANTS AND THEIR DETECTION.

The table on p. 335 gives the principal adulterants of the various substances used in painting, and some simple tests for them.

The presence of baryta is not necessarily harmful, but it is a cheaper material than either of those for which it may be substituted.

Natural ochre earths may properly be sold as natural iron oxides, and yet contain very little oxide of iron and leave a gritty instead of a smooth surface on drying.

Material.	Adulterants.	Test.
Linseed oil	Resin oil Fish oil Mineral oil Cotton-seed oil	Rub a few drops between the hands, adulteration can then be detected by the sense of smell.
Turpentine	Petroleum spirit Resin spirit Shale naphtha Coal-tar naphtha	
White-lead Zinc white	Baryta Chalk or whiting Gypsum China clay Only necessary in mixed paint.	Place a few drops in a porcelain crucible, warm gently over gas or spirit, and observe odour to detect any adulteration of oil or turps. Increase the temperature until oil and spirit ignite, and consume till only ash remains.
Red-lead	Baryta Red brick-dust Oxide of iron	When cold, transfer to, or if substances be unmixed place in glass beaker and boil in excess of nitric acid, strong at first and subsequently diluted with distilled water. Any residue will be an adulterant, baryta as a white powder, and brick-dust and ochre as a powder, while oxide of iron will impart a yellow colour to the acid solution.
Oxide of iron	Baryta Burnt ochre	

The drying power of a paint may be tested by spreading a thin film upon glass, when it should dry at a temperature of 60° Fahr. in forty-eight hours. If it fails to do so it probably contains some non-drying oil, which can be detected by the scent, as described above.

The presence of resin causes paint to crack after a time, and sometimes to become tacky after drying; while the presence of driers in excess produces the same effect.

KNOTTING AND STOPPING.

Knotting and stopping, operations which are precedent to painting upon woodwork, are accomplished by the use

of substances which have acquired the names of the operations themselves.

The operation of "knotting" is that of covering over the knots in timber, or of "killing" them (by lime-burning), in order to prevent the exudation of turpentine from them; and any substance used for knotting is known as "knotting," those principally employed being:—

Hot Lime.	Ordinary Knotting.	Patent Knotting.
Left on for 24 hours, then scraped off and surface coated with size knotting; or, alternatively and in bad cases, the surface is painted with red and white lead ground in oil, and when dry rubbed smooth with pumice-stone.	Applied in two coats; the first (known as size knotting) is made by grinding red lead in water and mixing it with strong glue size. It is used hot, dries in about ten minutes, and prevents exudation. The second coat consists of red-lead ground in oil and thinned with boiled oil and turpentine.	Chiefly shellac dissolved in naphtha. A similar knotting is made of the following substances, which must be kept in a warm place while the shellac dissolves, and frequently shaken:— $\frac{1}{4}$ pint Japanners' gold size, 1 teaspoonful red-lead, 1 pint vegetable naphtha, 7 ozs. orange shellac.

"Stopping" generally consists of oil putty, when the woodwork is to be covered with opaque paint, the object being to fill up any slightly open joints or cracks, but in varnished work, or with oiled or French-polished hard wood, putty would be unsightly, and beeswax is substituted.

REMOVING AND CLEANING OLD PAINT.

Old paint is generally removed by burning and scraping, but several substances are now known which, on being applied to paint, convert it into a species of soap, effecting its removal cheaply, effectually, and rapidly.

EXTRACT OF LETHIRIUM, a ready-made preparation, removes paint very quickly, the pure extract being thinly brushed over the surface twice or thrice; while, if there be

only one coat of paint to remove, it should be first diluted with thirty times its bulk of water. Before another coat is added, however, the extract must be carefully washed off with vinegar and water.

Messrs. Chancellor & Co.'s "STRIPSO" is simply painted on the surface, allowed to stand a short time, and then washed off with clean cold water—either fresh or salt. One cwt. is said to thoroughly cleanse a surface of 4,700 square feet (520 square yards), leaving it free for repainting at once, at very small cost; while it not only removes oil paint, but rust or baked enamel from iron, and varnished paper from plaster walls.

The following mixture, applied hot, and left for from 12 to 24 hours, enables old paint to be washed off with *hot* water:—

Dissolve 2 ozs. Soft Soap, 4 ozs. Potash, in boiling water, and add ½ lb. Quicklime.

Old paint can be *cleaned* by washing with a solution of pearlash in water; by treating with fresh quicklime mixed in water, washed off and reapplied repeatedly, this being best if the surface is greasy; by treating with Extract of Lethirium diluted with 200 times its bulk of water.

Chapter XXXVIII.

PAINTS: PROPORTIONS FOR VARIOUS COATS —DURABILITY—CLEANING METAL BEFORE PAINTING.

THE proportions in which the ingredients of a paint are used vary largely, often according to the personal fancy only of an irresponsible and unscientific painter, but even in experienced hands according to climate, quality of materials, and many other considerations. It is now becoming more and more the custom to purchase paints ready mixed by reputable firms, and so long as these are not tampered with, and are used as directed, and under the conditions for which they are intended, it would be well-nigh impossible to improve upon the practice. The following table must be accepted accordingly as being approximate only—for use on internal woodwork when all the materials are of good quality.

Coat.	White-lead.	Red-lead.	Raw Linseed Oil.	Turps.	Litharge or Patent Driers.	Number of Super. Yards Covered.
	lbs.	ozs.	pints.	pints.	ozs.	
1st Coat (Priming) ...	10	1	4	0	2	63
2nd Coat	10	0	$2\frac{1}{2}$	$1\frac{1}{2}$	2	100
3rd and Subsequent Coats.	10*	0	2	2	2	113

* This includes colouring matter, with which white-lead is replaced according to the tint required.

Sometimes, for internal work, a last coat, known as "Flatting," is added, which, made without oil and with

turpentine only, dries with a uniformly matt surface, free from gloss.

For external use, the most essential characteristic of a paint is durability, especially when it is applied as a protective coating to exposed structural steelwork. It is now usual to specify that the first coat at least upon steel shall consist of red-lead, and the wisdom of this is fully borne out by an exhaustive series of experiments, which are described in *The Engineer* for July 14th, 1899. Fifty-one iron plates were coated, each with a different, carefully prepared paint, as nearly as possible under similar conditions. Each painted iron strip was placed in a clean wide-mouthed glass bottle half filled with clean pure water; the bottles were not closed, but were placed side by side on a shelf in the laboratory immediately under the table. The mouth of the bottles did not quite touch the under side of the table, so that, although there was free access of air to the painted plates, yet dust and other impurities were kept out. The bottles were allowed to remain untouched for three months. After about a week several of the plates had begun to corrode; this was shown first by a cloudiness in the water, which afterwards became further oxidized and formed a red precipitate of ferric oxide, or rust, which subsided partly to the bottom of the vessel. After the three months' exposure the plates were removed, and the liquid in each bottle, together with the sediment, was carefully tested for the percentage of iron present in the form of rust; this figure was taken as denoting the amount of corrosion, but in every case was rather below the actual amount, as it did not include the portion which adhered to the iron plate.

In each case the weight of rust found by experiment was calculated in lbs. of rust per 1,500 square feet of painted surface, and this amount is set down in the second of the two columns of figures; the first column shows the percentage composition of the various paints employed. A

few of the results only are given below, but they well represent the remainder :—

	Per cent.	Rust in lbs. from 1,500 sq. yards, after three months.
Red-lead Paint—		
Red-lead	88·88	
Raw linseed oil ...	11·12	... ... none
	100·00	
"*A*" *Red-lead Paint—*		
Read-lead	45·00	
Barytes	45·00	... ... none
Raw linseed oil ...	10·00	
	100·00	
"*B*" *Red-lead Paint—*		
Red-lead	22·00	
Barytes	66·00	... ... none
Raw linseed oil ...	12·00	
	100·00	
Pure Zinc-white Paint—		
Zinc white (zinc oxide)	87·30	
Refined linseed oil ...	12·70	... ... traces
	100·00	
"*A*" *Zinc-white Paint—*		
Zinc white	45·00	
Barytes	45·00	... ... traces
Refined linseed oil ...	10·00	
	100·00	
"*B*" *Zinc-white Paint—*		
Zinc white	27·27	
Barytes	63·63	... ... traces
Refined linseed oil ...	9·10	
	100·00	

	Per cent.	Rust in lbs. from 1,500 sq. yards, after three months.
White-lead Paint—		
White-lead	92·56	
Refined linseed oil ...	7·44	75
	100·00	
"A" White-lead Paint—		
White-lead	53·78	80
Barytes	40·33	
Refined linseed oil ...	5·80	
	100·00	
"B" White-lead Paint—		
White-lead	50·52	
Barytes	42·10	95
Refined linseed oil ...	7·38	
	100·00	
Yellow-ochre Paint—		
Barytes and calcium carbonate	69·69	
Lead chromate ...	13·26	107
Turkey umber ...	2·65	
Raw linseed oil ...	14·40	
	100·00	
Barytes Paint—		
Barytes (natural barium sulphate)	88·00	
Raw linseed oil ...	12·00	155
	100·00	

	Per cent.	Rust in lbs. from 1,500 sq. yards, after three months.
Pure Prussian-blue Paint—		
Prussian blue... ...	48·27	
Raw linseed oil ...	51·73	221
	100·00	
Ivory-black Paint—		
Drop black (charcoal black)	60·00	
Boiled oil	40·00	250
	100·00	
Boiled linseed oil ...	100	500

These results bring into prominence the want of durability of linseed oil alone, the improvement effected by mixing with it even a weak pigment, the high value of the red-lead and zinc-white bases, and the comparatively little deterioration resulting from even large adulteration of these with baryta.

Cleanliness of metal before applying a protective coating is absolutely essential, and is a most important primary factor towards preservation: that is, absolute freedom from moisture, dirt, shop grease, flash scale and rust. Shop grease can be removed by repeated applications of benzine or lye water, afterwards washed with warm water and dried with cloths, or by the aid of heat. Rust and flash scale may be removed successfully by the sand blast, or with steel brushes and scrapers, and by "pickling" (treating with weak acid). Deep-seated rust spots should have heat applied to them, the usual method being the use of an ordinary painter's torch; this converts the rust into a new body, viz., peroxide of iron, which is easily removed by simply dusting off from the surface to be painted.

TABLE I.—SPECIFIC GRAVITY OF TYPICAL PIGMENTS.

(J. Cruickshank Smith.)

Oxide of zinc ...	5·65	Chemically pure sample.
Ditto	5·60	Commercial sample.
White-lead ...	6·60	Highest figure found for English stack-made.
Ditto	5·48	Commercial sample.
Ditto	5·51	American stack-made.
Ditto	5·64	German chamber-made.
Ditto	5·86	Belgian stack-made.
Barytes (best white)	4·02	Commercial sample.
Oxide of iron ...	5·12	Chemically pure.
Purple brown ...	4·23	Commercial sample.
Red-lead ...	8·62 to 9·19	Commercial sample.

TABLE II.—COVERING OR SPREADING POWER OF TYPICAL PAINTS.

(G. H. Hurst.)

The figures represent square feet covered by 10 lbs. of paint of the usual consistency, applied evenly with a brush.

On Wood.

	1st Coat.	2nd Coat.
Red-lead	112 ...	252
White-lead	221 ...	324
Oxide of zinc	378 ...	453
Red oxide	453 ...	540
Raw linseed oil	756 ...	872
Boiled linseed oil...	412 ...	540

On Metal.

Red-lead	477
White-lead	648
Oxide of zinc	1,134
Red oxide	870
Raw linseed oil	1,417
Boiled linseed oil	1,296

On Plaster.

Red-lead	324	On sized wall.
White-lead ...	352	On sized wall.
Oxide of zinc ...	504	On sized wall.
Raw linseed oil ...	55	1st coat, 99 2nd coat, on unsized wall.

TABLE III.—RELATIVE COST OF TYPICAL PAINTS ON A TWENTY YEARS' BASIS.

(J. Cruickshank Smith.)

Covering Capacity.—Calculated from the figures given by Mr. G. H. Hurst that 10 lbs. of the following paints cover on metal :—

White-lead	648 sq. ft.
Zinc white	1,134 „
Red-lead	477 „
Red oxide	870 „

Durability.—The relative figures are those currently accepted by British and American engineers.

Cost.—This is estimated at what is probably a maximum figure for the very best materials in large quantities.

The paints here mentioned are understood to be supplied ready for the brush, and to be made with special reference to the purpose for which they are to be used.

——	White-lead	Zinc White.	Red-lead.	Red Oxide.
Covering capacity in square yards per cwt.	806	1,411	594	1,083
Price per cwt. in shillings	32*s.*	36*s.*	32*s.*	28*s.*
Cost (in shillings) per 100 sq. ft. ...	·44	·28	·60	·28
Times painted in 20 years	5	5	3	7
Cost (in shillings) per 100 sq. ft. for 20 years.	2·20	1·40	1·80	1·96
Relative economic value on 20 years' basis, the highest value being represented by 100.	64	100	77	71

Chapter XXXIX.

COLOURING PIGMENTS.

COLOURING PIGMENTS are obtained from such a variety of sources that their method of preparation also varies of necessity to a considerable extent. As a general rule, however, as gathered from a visit to the works of Messrs. Lewis Berger & Sons, the various components, many of which are not divulged, are mixed by hand in water in large tanks, being stirred up with oars. When thorough mixture is secured, the pigment is allowed to settle and the water is drawn off. The sediment is then either pumped into a press which squeezes out most of the remaining water and converts the solids into cakes, or else it is drained of its water through cloths by hand, some of the more plastic pigments being incapable of treatment in presses. In either case, the semi-dry remainder is then put on racks in drying chambers, kept at different temperatures for various colours, some colours, notably ivory black, lake and flake white, being first pushed through a funnel and so formed into cones, known as "drops" (see Fig. 176), and sold in this form when dry; though they can equally well, and more cheaply, be dried in rough lumps.

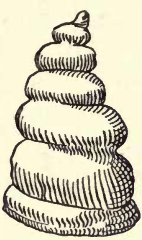


Fig. 176.
"Drop."

Most colours, however, are ground to powder after drying, and are sold in powder form.

Of late years, there has been a great tendency on the part of painters to buy their colours ready mixed, as mixing can be much better and more economically done

by the manufacturer with good machinery than by the small user; and this is met by mixing the powder pigments to the required tints with the correct proportions of white-lead and linseed oil in pug-mills and then passing the mixture, for the finer tints at least, between cone-shaped granite grind-stones with oil and varnish, the colour thus produced being packed in air-tight tins.

Some few colours, exceedingly useful for distemper, will not combine with oil, and so cannot be sold in a ready-mixed condition, but most are to be obtained in all three forms, in lump, in powder, or as mixed paint; and this is worth noting, especially with regard to those which are commonly supplied in the dry "drop" form, as it is erroneously and commonly imagined that they are not genuine in any other condition.

The following table of ordinary pigments may be useful:—

Colour.	Composition or Origin, etc.	How Prepared.	Characteristics.
BLACK.			
Ivory Black ...	Ivory chippings.	Roasted in closed iron tubes having a small vent only for escape of gases, and so completely charred. Then "levigated" (ground in water), "dropped" and dried, or dried in lump, and reground.	Intense velvety black. Very durable. Works well in all mediums.
Bone Black ...	Bone chippings.	Do.	An inferior substitute for Ivory Black.
Lamp Black ...	Oil, resin, resinous woods or tallow.	Burnt to produce soot, which forms the pigment.	Fine powder. Dense black. Durable. Works smoothly, and is fast to light. Dries badly in oil.
Vegetable Black...	Oil.	Do.	A superior form of Lamp Black. Very light, free from grit, and of good colour. Should be mixed with boiled oil, driers, and a little varnish. Raw linseed oil or turps keep it from drying.
Blue Black / Frankfort Black	Vine twigs.	Charred and treated like Ivory Black.	

TABLE OF ORDINARY PIGMENTS—*continued.*

Colour.	Composition or Origin, etc.	How Prepared.	Characteristics.
BLACK—*contd.*			
Grant's Black Bideford Black	A silicious mineral substance.	Ground.	Denser than Lamp Black. Less staining power. Used in silica paints.
BLUE.			
Prussian Blue Antwerp Blue Berlin Blue Haarlem Blue Chinese Blue	Prussiate of Potash ($K_4Fe(CN)_6$). Green Copperas (Sulphate of Iron) ($FeSO_4$, 7 H_2O). Alum ($Al_2(SO_4)_3$, K_2SO_4, 24 H_2O). Acids.	Mixed in excess of water, allowed to settle, excess of water drawn off and fresh water added. Process repeated several times. Strained or pressed, dried and ground.	Many different shades due to slight variations in proportions of constituents, known by different names. Dries well in oil. Much used for dark tints, making purples and intensifying black. Durable and fast to light.
Indigo	Plants found in Asia and America.	Steeped in water and fermented.	Transparent. Works well in oil or water. Not durable, especially with lead.
Ultramarine (true)	Lapis Lazuli.	Ground.	Very costly.
French and German Ultramarine.	Soda, Silica, Alum, and Sulphur.	Fused, washed, reheated, ground.	Used mostly for wall papers. Fast to light.
Cobalt Smalt Saxon Blue Royal Blue	Ore.	Roasted and ground.	Works well in water, and is fast to light.
Celestial or Brunswick Blue. Damp Blue	Chemical.	As usual.	
Bremen Blue Verditer.	Copper and Lime.	As usual.	Greenish hue.
Blue Ochre ...	Natural Clay.	Ground.	Permanent.
YELLOWS.			
Chrome Yellow	Bichromate of Potash ($K_2Cr_2O_7$). Acetate of Lead ($Pb(C_2H_3O_2)_2$). Nitrate of Lead ($Pb(NO_3)_2$). White Lead (2 Pb CO_3, $Pb(HO)_2$).	Dilute solutions of bichromate of potash and acetate of lead or nitrate of lead are mixed. This produces a medium tint, called *Middle Chrome.* The addition of lead sulphate ($PbSO_4$) produces a pale tint, called *Lemon Chrome.* The addition of caustic potash gives a darker tint, called *Orange Chrome.*	Mixes well with oil and with white-lead in oil or water. Fairly permanent if kept clear even in sunlight, but darkens in bad atmosphere.
Naples Yellow ...	Antimony, Lead.	It is a salt of lead and antimony.	Not so brilliant as Chrome Yellow. Difficult to grind.
King's Yellow, also called *Chinese Yellow*, *Arsenic Yellow*, *Yellow Orpiment.*	Arsenic.	...	Not durable, and injures several other pigments when mixed with them.

TABLE OF ORDINARY PIGMENTS—*continued.*

Colour.	Composition or Origin, etc.	How Prepared.	Characteristics.
YELLOWS.—*contd.*			
Turner's, Cassel's, Verona, Montpelier Patent Yellow.	Oxichlorides of Lead.		
Cadmium Yellow	Sulphide of Cadmium.	...	Fast to light.
Yellow Ochre ...	Natural Clay, coloured by Oxide of Iron.	Ground only.	Found in many parts of England. Not very brilliant. Much used for distemper work. It does not lose its colour when mixed with lime, and is fast to light.
Spruce Ochre ...	Do.	...	Yellowish brown colour.
Oxford Ochre ...	Do.	...	Warm yellow colour, has a soft texture, and is absorbent of both oils and water.
Stone Ochre ...	Do.	...	Found in the form of balls embedded in the stone of the Cotswold Hills.
Raw Sienna or Terra de Sienna.	Clay stained with Oxides of Iron and Manganese.	...	Dull yellow in colour. Durable in oil and water. Used in graining.
Yellow Lake. (See Lake).	Tumeric and Aluminium Hydrate $[Al_2(HO)_6]$.	...	Is not durable. Does not mix well with oil and metallic colours.
BROWNS.			
Raw Umber ...	Clay, coloured with Oxide of Iron.	Ground only	Obtained from Turkey and Cyprus. Very durable in oil and water. Does not injure other pigments when mixed with them. Fast to light.
Burnt Umber ...	Do.	Roasted in large ovens and ground.	Darker colour than Raw Umber. Useful as a drier, and mixes with white-lead to form and tone colour. Fast to light.
Vandyke Brown...	Earthy mineral.	Ground only.	Dark brown colour. Mixes well with oil and water, is useful for graining, and is fast to light.
Purple Brown ...	...	...	Reddish-brown colour. Is mixed with boiled oil, and a little varnish and driers for outside work.
Burnt Sienna ...	Natural Clay, stained with Oxides of Iron and Manganese.	...	Darker colour than Raw Sienna. Used for shading gold, and is fast to light.
Brown Ochre ...	...	...	Same as Spruce Ochre.
Spanish Brown ...	...	...	Also an Ochre.

TABLE OF ORDINARY PIGMENTS—*continued.*

Colour.	Composition or Origin, etc.	How Prepared.	Characteristics.
BROWNS—*contd.*			
Brown Pink ...	Vegetable pigment.	...	Often has a greenish hue. Works well in water and oil, but dries badly, and will not keep its colour when mixed with white-lead.
Bistre	Wood or Peat Soot.		
Vandyke Brown, Cassel's Earth, Egyptian Brown	Bituminous Earth.		
Asphaltum ...	Bitumen.	...	Cracks on drying.
Sepia	Fluid found under the Shell of a Cuttlefish.	...	A most useful colour. Works well, especially in water.
REDS.			
Carmine	Cochineal Insect.	...	The most brilliant red pigment known. Expensive for ordinary house painting, and is not durable.
Red-lead	Composition uncertain, usually expressed Pb_3O_4.	By heating lead carbonate ($PbCO_3$) or lead monoxide (PbO) to a temperature not above 450° C. Ground with oil or varnish.	Durable by itself. May be mixed with ochres. White-lead or metallic salts destroy its colour.
Vermilion... ...	Cinnabar and natural Sulphide of Mercury (HgS.), found in Spain, California and China.	Ground only.	Very durable. Fast to light (sometimes adulterated with red-lead, when it will not weather well). Can be tested by heating in a test tube; if it entirely volatilises it is genuine.
Artificial Vermillion.	Sulphur and Mercury.	Made of mercury and sulphur. The sublimate is the red sulphide of mercury.	
Antimony Vermillion.	Antimony and Sulphur.		
German Vermillion.	Antimony Pentasulphide (Sb_2S_5)	Antimony pentachloride is mixed with water, and sulphuretted hydrogen is passed through the solution when the pentasulphide is formed.	Orange-red in colour.
Indian Red ..	Hæmatite (Fe_2O_3).	Ground only. Sometimes prepared artificially by calcining sulphate of iron.	Tints vary, but rosy hues are considered best. Used with turpentine and a little varnish to produce a dull surface, drying rapidly. With boiled oil and a little driers it produces a glossy surface, but dries more slowly. Fast to light.

TABLE OF ORDINARY PIGMENTS—*continued.*

Colour.	Composition or Origin, etc.	How Prepared.	Characteristics.
REDS—*contd.*			
Chinese Red ...	Chromates of lead.	By boiling white-lead with a solution of bichromate of potash.	
Persian Red ...	Do.	Do., with addition of sulphuric acid.	
Light Red... ...	Burnt Ochre.	...	Not very brilliant. Used for distemper. Is not affected by light or air.
Venetian Red ...	...	By heating sulphate of iron. When pure is called *Bright Red.* Sometimes adulterated by adding sulphate of lime during its manufacture.	Fast to light.
Rose Pink... ...	Whiting or Chalk, Logwood.	The chalk is stained by the colour extracted from logwood by boiling with water.	Fades quickly. Used for wall papers and distemper.
Dutch Pink ...	Whiting or Chalk, and Quercitron Bark.		
LAKES.			
Drop Lake ...	Aluminium Hydrate ($Al_2(HO)_6$), and Brazil Wood.	The colouring matter is extracted from the Brazil wood by boiling with water. This is mixed with aluminium hydrate held suspended in water. The colouring matter combines with the aluminium hydrate and settles to the bottom; the water is decanted off, and the pigment is then dropped through a funnel on to a slab. The drops are dried and mixed into a paste with gum water. It is sometimes called *Brazil Wood Lake.*	Is not durable, and is very expensive.
Scarlet Lake, Florentine Lake, Hamburg Lake, Chinese Lake, Roman Lake, Venetian Lake, Carminated Lake	Aluminium Hydrate ($Al_2(HO)_6$), and Cochineal.	It is made in a similar manner to "Drop Lake," but the precipitated colour is dried, causing it to split up into small pieces. It is then ground and mixed with oil.	It is not durable, and is very expensive.

TABLE OF ORDINARY PIGMENTS—*continued.*

Colour.	Composition or Origin, etc.	How Prepared.	Characteristics.
ORANGES.			
Chrome Orange ...	Chromate of Lead ($PbCrO_4$).	It is produced by a precipitation from a lead salt, with either potassium chromate or dichromate. It forms under these conditions a bright yellow powder.	It is brighter than Vermillion, but less durable.
Orange Ochre ...	Bright Yellow Ochre.	Yellow ochre is burnt to give warmth of tint. It is sometimes called *Spanish Ochre.*	It dries and works well in water and oils. Is very durable.
Mars Orange ...	Ochre.		
Orange Red ...	Lead Oxide.	It is produced by a further oxidation of red-lead.	It is a brighter and better pigment than Red-lead.
GREENS.			
Brunswick Green	Copper Oxychlorides.	It is produced by the action of bleaching powder or salammoniac on cupric sulphate. Chalk, lead, and alum are sometimes added.	It has rather a bluish tinge; dries well in oil, and is not poisonous.
Do.	Also Chromate of Lead, Prussian Blue, and Sulphate of Barium.	The constituents are simply mixed together.	
Mineral Green ...	...	It is made from basic carbonate of copper ($CuCo_3$, $Cu(HO)_2$).	It weathers well.
Verdigris	Acetate of Copper.	Sodium carbonate added to a solution of copper sulphate forming the basic carbonate of copper ($CuCo_3$, $Cu(HO)_2$).	It dries rapidly, but is not a safe pigment to use. It has a bluish-green hue, and is durable in oils and varnish, but not in water.
Green Verditer ...	Carbonate of Copper and Lime.		
Prussian Green ...	Prussian Blue and various Yellow Pigments.	Formed by mixing Prussian blue with various yellow pigments.	Usually not so durable as natural greens.
Brighton Green Malachite Green Mountain Green Marine Green Saxon Green African Green French Green Patent Green etc., etc.	Compounds of Copper.		
Emerald Green ...	Verdigris and Arsenious Acid.	Verdigris is mixed with a solution of arsenious acid.	It is a very brilliant colour, very poisonous, difficult to grind, and dries badly in oil.
Schelle's or Mitis Green and Vienna Green.	Arsenites of Copper.	...	Very poisonous.

TABLE OF ORDINARY PIGMENTS—*continued.*

Colour.	Composition or Origin, etc.	How Prepared.	Characteristics.
GREENS—*contd.*			
Chrome Green ...	Oxide of Chromium (Cr_2O_3).	...	Very durable, and is fast to light
Guignet's Green...	Hydrated Chromic Oxide (Cr_2O_3, $2H_2O$).	Potassium dichromate and boric acid are heated to a dull redness, and the mass treated with water.	
Terre Verte ...	Natural Coloured Clay.		
Rinman's Green ...	Cobalt and Ferrous Oxide of Lime.		

Chapter XL.

SPECIAL PAINTS—ENAMELS—IRON PRESERVATIVES—ENAMELLING—STONE PRESERVATIVES AND DAMP WALL SOLUTIONS —FIRE-RESISTING PAINTS.

THE composition of most of the special paints, now upon the market under well-known trade names, is secret, so that it is possible here to do little more than name the most prominent of them, drawing attention to some of their more obvious characteristics. They should all be used strictly in accordance with the directions supplied with them, without dilution or mixture of any kind.

"VELVRIL" is made with nitrated castor oil in place of linseed oil. This forms a thin and flexible skin which is absolutely impervious to water and non-corrosive. It is claimed for it that it resists acetic and mineral acids, diluted ammonia, and mineral and other oils; and that it is absolutely water-proof, oil-proof, rust-proof, and acid-proof, and resists all noxious gases. It can be made with metallic colours, such as aluminium, bronze, etc.; or in various colours, such as stone, red, green, slate, brown black, white, etc., or to any specification for a particular purpose.

Its covering powers compare favourably with any ordinary oil paint, while its odour is not unpleasant, and disappears within two hours of its application.

It is said to be antiseptic, and possess antiseptic properties; while it can be washed with antiseptic solutions, and consequently is specially suitable for hospitals, operating halls, etc.

It is said that work which was done five years ago with

this paint is still perfectly good, and the paint stands acid and sulphurous fumes in a very remarkable manner.

Priming colours are specially prepared as a groundwork for the finishing coat, and should be used in all cases where two coats are required.

The paint is easy to work and quick drying, giving a smooth, hard surface.

Chancellor's "VELURE" and Gay's "IMPENETRABLE PAINT" are apparently similar to "Velvril," drying more slowly with a slight gloss, and somewhat "tacky" in use; but both are very durable and satisfactory, whether used on wood or metal, internally or externally.

"RIPOLIN" is a varnish or enamel paint made with a gloss or flat finish, said to have all the qualities of the best varnish, combined with great covering, wearing and anti-corrosive properties. It is suitable for indoor or outdoor work, resisting to a remarkable degree atmospheric influences, steam, heat, ammonia, and sulphurous vapours, is applicable for the highest decorative work, and at the same time, owing to its wearing properties, is economical for plain painting, having double the lifetime of the best white-lead paints. It is also suitable for painting surfaces exposed to the sea air and spray, being a perfect marine paint.

Flat Ripolin is superior to the ordinary flatting, as it dries with a beautiful surface as smooth as silk, while it can be applied outdoors if necessary, and will wash as well as varnished work. In this respect it is unique, as ordinary flatting will not wear or wash properly, is easily soiled, and can only be applied on indoor work.

Gloss Ripolin must be applied freely, and when so used will flow like a varnish. Whenever two coats of Ripolin are applied, the first coat should be a poor or thin coat, and then felted down like varnished work to receive the final full coat of Ripolin.

Flat Ripolin usually requires two coats, and must be freely used and applied somewhat like flat varnish;

although it is different in many respects, as it dries slowly, and about forty-eight hours must intervene before applying the final coat. Wall surfaces may be stippled. Flat Ripolin has good covering qualities, so the first coat can be substituted for one of the usual ground coats.

The undercoating to Flat Ripolin should be made as for ordinary flatting, and if stained to finishing colour, one coat of Ripolin will frequently suffice.

Aspinall's DECORATORS' ENAMEL is apparently similar to Ripolin and is also supplied both matt and glossy.

Several BATH-ENAMELS are upon the market, made by reputable firms, for the interior of baths and to withstand hot water; while the Indestructible Paint Co. supply Gold and Aluminium Enamels also.

Blundell's BLACK PETRIFYING LIQUID, for the protection of steel and iron from rust, is said to be more lasting and effective than any other kind of paint, especially if applied over a coat of their BLACK PETRIFYING PRIMING, which contains strong anti-rust properties. In appearance it compares with the best black Japan varnish, and stands heat, and is therefore suitable for boiler fronts, steam and hot-water pipes, stoves, grates, etc. It stands stoving, and will neither crack nor chip.

"CARBOLIZING COATING," made by the Goheen Manufacturing Co., for use upon structural steel and iron work, is said to have a life of eight years and to be of great covering power, while the same makers produce a substance known as "GALVANUM," which is the only paint made that will adhere properly to new galvanized iron, before the protecting value of the galvanizing coating has been sacrificed by exposure to weather.

Both Carbonizing Coating and Galvanum form perfect bases for any finishing coat of any oil colour.

STONE PRESERVATIVES AND DAMP WALL SOLUTIONS.

Szerelmey's STONE LIQUID is not a paint, and must not be treated as such. It is intended to be absorbed into the masonry, and not to lie on the surface. All porous work must have copious treatment. Sand stockbricks, and very open freestone require, in some cases, four coats to complete the treatment. When a glaze shows itself, it is an indication that the treatment is complete. The liquid thoroughly waterproofs the masonry, but does not alter its appearance, or have any chemical effect upon it.

The best time for using it is in dry, hot weather; or in India and Australia in the hot season, before the rains commence. It should be rubbed in well with a stiff brush.

Browning's DAMP WALL SOLUTION, made by the Indestructible Paint Co., is similar in method of application and effect. It is claimed for it that:—

1. The solution is colourless.

2. It leaves no deposit on the surface, and being invisible, it does not in any way alter the appearance of the coarsest stone or whitest marble. It need hardly be said that anything in the nature of a paint which should destroy or conceal the grain of stone is altogether inadmissible.

3. No vegetable or green appearance can be generated after its application.

4. Bricks, and the softest stone, and even chalk, are rendered by it thoroughly and lastingly weather-proof, not only against ordinary rain, but in the most exposed seaside situations.

Blundell's PETRIFYING LIQUIDS are specially manufactured in different varieties, to comply with the following requirements:—

1. A clear transparent solution, which is known as "Outside Flat-drying Transparent Petrifying Liquid," for the

preservation of exterior stone, brick, etc., from decay. This has the property of penetrating any porous surface, whether stone, brick, or cement, to a considerable depth; it then slowly dries, filling up the pores, binding the particles together, and forming a really water-proof and durable surface, which is proof against the destructive effects of frost on a wet and porous surface. It also excludes and prevents any deleterious effects caused by the atmosphere in towns, and being practically colourless and transparent, only very slightly affects the external appearance of the surface over which it has been applied, and has no tendency to darken or discolour with age.

2. A second object is to cure the interior surface of damp walls, so making them safe for subsequent painting, colouring, papering, etc. A somewhat different kind of Transparent Petrifying Liquid is generally used for this purpose.

3. The largest use for the Petrifying Liquids is for producing a white or coloured enamel-like appearance (either glossy or matt) over interior wall surfaces. In this way Petrifying Liquids may be looked upon as a much cheaper and yet satisfactory substitute for glazed-brick or tile; and they even have an advantage over the latter, inasmuch as there are no semi-porous cement or mortar joints to catch any dirt or infection.

These liquids have great covering power, one gallon being sufficient to cover 40 square yards one coat. In all cases two coats are recommended.

Messrs. J. S. Williams & Sons' DAMP-RESISTING FLUID is only adapted for inside walls; from which all old paper should be removed.

New plaster on old walls, when hard enough to resist the pressure of the brush, may be painted or papered immediately the fluid is dry. It dries in about six hours, and becomes very hard.

FIRE-RESISTING PAINTS.

CYANITE is a colourless preparation which can either be applied with a distemper brush, or into which light fabrics can be dipped, rendering them incapable of bursting into flame, and though they will still smoulder and slowly consume where actually exposed to fire, they greatly retard its spread.

MAGNITE has similar properties, but it is opaque. It can be used as the first coat for painting with ordinary colours.

Chapter XLI.

VARNISH—FRENCH POLISH AND LACQUERS —ENAMEL PAINTS AND JAPANS—STAINS.

GUMS, or the exudations of certain trees, mostly pines, in a soft or viscuous form, contain, as a rule, two substances, one an essential oil, and the other a resin. When the essential oil is evaporated, resin alone is left, and this, dissolved either in linseed oil, turpentine or alcohol (methylated spirit) forms VARNISH.

Roughly speaking, varnishes may be divided under two headings, viz., OIL VARNISHES and SPIRIT VARNISHES, the former being composed of a compound of hard gum and linseed oil, thinned to the right consistency with turpentine, and the latter being prepared by dissolving another class of gum in spirits of wine (methylated spirit). The oil varnishes alone are suitable for exterior work, and are always much harder and more durable. Quick-drying spirit varnish is only suitable for indoor fancy work, and owing to its brittle nature, is easily bruised and injured.

There are other, sometimes called spirit, varnishes which should be more strictly called turpentine varnishes, these being prepared from gums or rosin, soluble in turpentine without oil. The most expensive is mastic varnish, almost exclusively used for varnishing oil paintings.

Whatever influence the solvent used may have on the quality of the resultant varnish, it is the uncharged resin alone which, after the evaporation of the solvent, constitutes the coat, and imparts to the varnish its distinguishing properties.

Hard resin gives bright but brittle varnish; soft resin gives varnish which produces lustrous but more elastic

coats, due to the essential oil contained in the resin, but the elasticity disappears as the essential oil disappears Finally, by dissolving several resins together, the objectionable features of some can be done away with, whilst the properties of others are modified, thus securing a varnish adapted in every way for the object in view, which possibly could not be obtained by the use of any one single resin.

What are generally known as Oil Varnishes are by far the most important class, and they may be divided into inside and outside oil varnishes, for the reason that there are many quick, hard, drying and comparatively cheap oil varnishes, that are suitable for interior work, but which are not sufficiently durable to long withstand the action of sun and rain and exposure to the weather.

TABLE OF RESINS.

Resin.	Where Found	Characteristics.	Use.
Amber	The Baltic	Hard and durable, keeps its colour well, and is tough, but difficult to dissolve, costly, and slow in drying.	Oil varnish for best work.
Animé	East Indies	Nearly as hard, durable and insoluble as amber, but not so tough, apt to crack, and darkens on exposure.	A quick-drying oil varnish.
Copal	East and West Indies and Central America	Sound and durable, lightens on exposure; imported in three qualities, according to colour, the lightest being kept for the highest class of work.	Oil varnish for general use.
Elemi	West Indies	Similar to Copal.	Similar to Copal

Resin.	Where Found.	Characteristics.	Use.
Lac	East Indies	More soluble than the above; imported as Stick-, Shell-, and Seed-Lac. The last is the palest, softest, and purest, and is used for making lacquers.	Spirit varnish.
Sandarach	...	Similar to Lac, but softer, less brilliant, and lighter in colour.	Spirit varnish.
Mastic	Mediterranean	Soft, and works easily,	Turpentine varnish for oil paintings.
Dammar	New Zealand	Very soft and nearly colourless.	Turpentine varnish, for wall papers or upper wall surfaces not exposed to wear.
* Rosin, or Colophony	Northern Europe and America	Produced from turpentine, it cracks and peels in use.	An adulterant to be avoided.

* It may be noted that while *Rosin* is a *Resin*, the two words are not synonymous.

According to Messrs. Blundell, Spence and Co. :—

"There is a great art in properly running the gum in the pots by heat, and using the proper kind of oil in the right proportion, and this proportion depends upon the kind and class of hard gum used. Besides this, the varnish should be of the right consistency, neither too thin nor too round; this depends upon having the right proportion of turpentine. Lastly, there is the proper maturing of the varnish, which should be kept for a considerable time in iron tanks, in a house properly warmed with hot-water pipes: this so-called ageing and maturing of the varnish gives it time to deposit

impurities and solid matter held in suspension; it also acquires other properties with age, causing it to flow better off the brush, to produce a more even brilliant surface, and one not liable to bloom.

"A man with some technical knowledge can test an inside oil varnish, by carefully spreading it over a given surface, noticing how it flows, the way and time in which it dries, and the appearance of the surface when dry.

"A varnish containing rosin, or even too much gum, very soon begins to get tacky. If there is too much rosin, the tackiness continues to the end, and though it appears to begin drying very well, it is a long time in properly hardening off. If there be too much gum it soon ceases to flow properly, and quickly gets tacky, but the tackiness quickly passes off, and the varnish dries off and hardens much too soon. This means a lack of durability, and great liability to bloom.

"No one can test the relative value and durability of an outside oak varnish, though by testing as above described, he can easily eliminate varnishes evidently not suitable for outside work. Those that pass this test can only be further proved by exposure to the weather, so that to arrive at the actual relative durability and merits of a selected number of makes of varnish must take something like six months, and even then a further six months' exposure will show unexpected defects in varnish which appeared to be perfectly satisfactory during the first period."

The commonest article used for reducing the cost and making cheap varnishes is rosin, which should be avoided in the manufacture of all varnishes, whether for interior or exterior use. A very small addition completely ruins varnish for outside use.

With regard to Spirit Varnishes, as shellac or sendarac do not perfectly dissolve in methylated spirit in the cold, it is necessary to effect the solution of these solids by the aid of a gentle heat. The aid of a sand or water bath is the usual means employed, so as to prevent the volatile spirit

becoming too hot, which would cause loss by vaporization of the spirit and the production of a thick magna, too stiff to lay on with a brush. Such varnishes dry with a more brilliant gloss than those made by the cold process, but their adherence is not so great.

As the knowledge and capacity for making first-class varnishes means many years' experience and great skill and technical knowledge, the best thing to do is to deal only with old-established houses of repute. They know what they are doing, and will not send out a really unsuitable article if they can possibly help it. Most manufacturers list their varnishes under names which denote the purposes for which they are intended to be used and not their constituents, there being little agreement in the nomenclature.

The following recipes and formulæ are by Mr. H. C. Standage :—

White Hard Spirit Varnish No. 1.

4 lbs. mastic resin.
8 „ sandaric resin.

Dissolved in 2 quarts methylated spirit and the compound thinned with 1 gallon of oil of turpentine.

White Hard Spirit Varnish No. 2.

12½ lbs. pale sandarac resin.
19½ „ pale soft manilla copal.
5 gallons methylated spirit.

White Soft Spirit Varnish.

½ lb. elemi resin.
½ „ sandarac resin.
1 oz. camphor.
½ gallon methylated spirit.

Brown Hard Spirit Varnish.

14 lbs. medium rosin.
28 „ button lac.
7 gallons methylated spirit.

Varnish Vehicle for Dark Enamel.

14 lbs. ground shellac.
28 „ dark sandarac resin.
28 „ medium rosin.
$3\frac{1}{2}$ „ gum benzoin.
15 gallons methylated spirit.

Transparent Varnish for Polished Surfaces.

20	parts sandarac resin		All parts by weight.
6	„ resin		
1	„ glycerine		

Methylated spirit (sufficient to dissolve the solids in).

Dissolve the solids in the spirit and then add the glycerine, which will render the varnish flexible.

Varnish for Varnished Steel to prevent Rust.

15 parts sandarac resin.
10 „ mastic resin.
5 „ elemi resin.
3 „ camphor.
5 quarts methylated spirit.

Dissolve the solids in the spirit by the heat of a water bottle, and apply cold.

Gold Varnish for White Metals.

50 parts orange shellac.
40 „ mastic resin.
39 „ Venice turpentine.
$22\frac{1}{2}$ „ Dragon's blood.
25 „ gamboge.
750 „ methylated spirit.

Digest the dragon's blood and gamboge in the spirit, then filter and dissolve the solids in the filtered fluid.

Red Varnish for White Metals.

20 parts shellac.
11 „ sandarac resin, powdered.
5 „ tumeric.
3 „ red sandal-wood.
3 „ essence of lavender.
140 „ methylated spirit.

Digest the tumeric and sandal-wood in the spirit, then strain, and dissolve in the filtered fluid.

Yellow Varnish for Metal.

1 pint gum lac.
4 „ amber resin.
8 „ turpentine.

Dissolve the resin and lac by heat and add the oil varnish to the melted resin and then put in the oil of turpentine.

FRENCH POLISH AND LACQUERS.

A form of varnish which is largely used for hard woods, especially mahogany, being applied by rubbing it into the previously sand-papered surface of the wood, is known by the distinctive name of French Polish. The simplest and possibly the best is made by dissolving 1½ lbs. of shellac in 1 gallon of methylated spirit; but other gums are sometimes used, and the polish may be darkened by adding benzine (with great caution owing to its inflammability), or may be coloured with dragon's blood.

It dries in about twenty minutes, and gives a firm, hard and lustrous coat, which is durable and weather resisting, but brittle. The addition of a little gum elemi or gum copal renders it elastic.

This also forms the basis of a large number of coloured varnishes sold under the name of walnut varnish, mahogany varnish, etc., all such colours being produced by the addition of suitable colouring matter to the spirit before or after dissolving the shellac therein.

An almost identical varnish is also known as LACQUER, different proportions of shellac and methylated spirit being used for different purposes. For application to hard wood—generally to turned articles, by means of a rag while they are on the lathe—2 lbs. of shellac is dissolved in 1 gallon of spirit; while for brass, if the work does not require to be coloured, a much thinner lacquer is used, $\frac{1}{2}$ lb. of the best pale shellac being dissolved with agitation in 1 gallon of spirit, and the mixture being allowed to stand and then filtered, it being constantly kept in the dark, as the effect of light is to darken its colour.

ENAMEL PAINTS AND JAPANS.

Though originally the term "enamel" was confined to vitreous enamels which were dried or baked by stoving, it has latterly been applied to a class of paints which dry with an enamel gloss, but otherwise differ from ordinary paints only in being compounded with a varnish (oleoresinous) vehicle instead of linseed oil and turpentine.

The nature of the oleoresinous vehicle employed varies considerably. For hard enamel coats, copal and water resins are made use of, but inferior varnishes are also employed; though enamel paints compounded of a varnish vehicle in which rosin or rosin oil is an ingredient is of comparatively little value because rosin and its compounds never permanently dry or harden, and the result is a soft, sticky coat.

Spirit varnish enamels are usually made by dissolving ruby shellac or sandarac resin, or mixtures of the two, in methylated spirit for the production of dark enamels, bleached shellac being used for pale ones. Cheaper grades, made with benzine or naphtha as a solvent, are valueless, there being no binding qualities in these quickly evaporating liquids.

To enable enamel varnish to adhere to metal, it is usual to dissolve in the finished varnish, before grinding up the pigment therein, ·5 to 1 per cent. of boracic acid crystals;

but not more than 1 per cent. should be used, otherwise it will have the opposite effect.

The range of solid colouring matters that can be used is large, but there are some limitations. For instance, zinc oxides will form zinc resinates with the resin in the varnish and then decompose the compound; while red-lead also is a prohibited pigment, because it combines with the resinous ingredients to form a solid body.

Japanning, like enamelling, is properly performed with the aid of heat; but the word "Japan" is often used to signify a black enamel paint of the above character—a confusion of terms which leads to much misapprehension.

Below are a few of Mr. H. C. Standage's recipes for black enamel paints and Japans.

Glossy Brunswick Black.

Run 45 lbs. asphaltum for six hours in a set pot. Boil 6 gallons of oil with 6 lbs. of litharge until it strings well. Pour this into the melted asphaltum and boil it until it sets hard between the fingers. When cooled down, thin with 25 gallons of turps. This dries in about four hours with a good glossy surface.

A Commoner Quality Brunswick Black.

Boil for six hours in the set pot 28 lbs. coal-tar pitch, and 28 lbs. asphaltum. Allow the mixture to stand all night, then boil it up and add 8 gallons of boiled oil, 10 lbs. of castings, 10 lbs. red-lead (these solids being added a little at a time), and then boil the mass until it sets hard between the fingers. Allow it to cool and add 20 gallons of turps. Dries in one to two-and-a-half hours.

Ordinary Brunswick Black.

21 lbs. dark rosin.
28 ,, common asphaltum.

Run together until liquid, boil and add 79½ lbs. American turps.

Black Japan Varnish, suited for Wood and Metal.

50 lbs. Naples asphaltum.
8 „ dark copal.

Fuse and add 12 gallons linseed oil, boil and add 10 lbs. dark amber resin (previously fused and boiled with 2 gallons of linseed oil), then add driers (red-lead and litharge)—a sufficiency.

Flexible Black Japan.

4 lbs. burnt amber.
2 „ asphaltum.
4 gallons boiled oil.
Turpentine (a sufficiency).

Boil the asphaltum first in a little oil at a moderate heat, then add the amber (ground in oil), and lastly the rest of the oil, and when well incorporated thin with turpentine to a suitable consistency.

Benzine Japan.

16 lbs. litharge.
16 „ powered black oxide manganese.
12 gallons linseed oil.
10 „ turpentine.
15 „ benzine.

Prepare as already described, but as the benzine is very inflammable the mass must be allowed to cool very considerably before adding the benzine, and such addition should be made in the open air, or at least where there is no source of naked flame near at hand.

Hard, Glossy, Black Japan.

Run 48 lbs. asphaltum in the set pot, and when melted, add 10 gallons of oil; run in the gum pot

8 lbs. of common gum arabic,

and mix with it 2 gallons of oil; pour the mixture and the asphaltum in the set pot, then run 10 lbs. common

amber, and mix with 2 gallons of oil; add them running to the mass in the set pot, and boil up the contents of same for three hours longer, during which time add—

7 lbs. red lead.
7 „ litharge, and
3 „ copperas,

and boil the mixture until it sets hard between the fingers, then thin with 30 gallons of turps.

Pure Turpentine Japan.

25 lbs. litharge.
27 „ black oxide of manganese.
45 „ kauri dust.
16 gallons well-settled and aged raw oil.
80 „ turpentine.

Berlin Black.

84 lbs. best asphaltum.
28 „ boiled linseed oil.
168 „ American turps.
70 „ common vegetable black.
14 „ slate litharge.

Run the asphaltum, boil the oil, previously boiled, with the litharge for two hours, allow it to cool, and add the turpentine in which the vegetable black has been rubbed up.

STAINS.

Stains are materials, supplied either in liquid or powder form (the latter being mixed with hot water before use), for application upon light-coloured woods, to give them a darker tone without obscuring the grain. The solution has to be applied freely, in one or two coats, and afterwards well sized (two coats being usually given) and varnished.

Stains to represent the colour of oak, mahogany, and walnut, are procurable in several shades from most paint

manufacturers, and a green oil stain is made by the Cyanite Paint Co. The following stains are, however, readily made :—

Mahogany Stain.—Burnt sienna ground in vinegar. A thin mixture serves for the ground work, if shaded and grained while wet with a mixture containing more sienna.

Black Walnut Stain.—Burnt umber ground in vinegar and treated as above.

Walnut Stain.—1½ oz. washing soda, 2½ oz. Vandyke brown, and ¼ oz. bichromate of potash, boiled together for ten minutes in a quart of water.

Oak Stain.—1 oz. each of American potash and pearlash dissolved in a pint of water. This should be kept corked, and needs dilution for the lighter tints.

Red Stain.—Dragon's blood dissolved in methylated spirit.

Black Stain.—Two coats are necessary, the first consisting of ¼ lb. logwood boiled in a quart of water, ½ oz. of pearlash being added and the mixture being used hot ; while for the second coat logwood is boiled in water as before, but the pearlash is replaced by ¼ oz. verdigris and ¼ oz. copperas. The mixture is strained and ¼ lb. rusty filings added.

Chapter XLII.

ENAMELLING AND JAPANNING — GILDING — WHITEWASH — COLOURING — WATER PAINTS.

VITREOUS ENAMELS for metals are produced by fusing a base or flux on the metal.

According to Mr. H. C. Standage :—

" For high-class enamel work, not less than three coats should be applied, each coat being stoved and rubbed down before the application of the next one. The enamel is applied with a brush for good work, but for common work the article is dipped in a trough of the enamelling compound, when one or two coats only are applied.

" The difficulty in securing the attachment of the enamel to *iron* is found in the chemical changes which iron undergoes when heated. Iron is a metal that has very great affinity for oxygen ; a drop of water allowed to dry on a piece of iron will leave a brown mark of iron rust. Again, when iron is subjected to a dry heat at a great temperature, oxygen from the air will also combine with the metal and produce on its surface a film of oxide of iron, which will be black or red in colour, according to the relative amount of oxygen that has combined with the metal. A fusive heat causes the greatest union, and produces a red oxide. Now, such a layer of oxide, even though it be but a mere film, will prevent the adhesion of the vitreous flux or base of which the enamel is composed. In the case of thin sheet iron, the mischief thus caused is more detrimental than in the case of thick iron vessels. To avoid this oxidation of iron it is usual to use a flux having a silicate of lead or a boro-silicate of soda base, which fuses at a lower

temperature than that productive of iron rust. The surface of the metal is cleansed of all grease, oxide, etc., by scouring it; then the flux is spread over its surface in the state of powder, and the metal put into the stoving oven until the flux melts, when it is well spread over the surface of the iron and forms a vitreous coating."

The enamelling stove or oven has to be such that a temperature of at least 400° Fahr. can be attained.

Transparent enamels are the base of all the coloured enamels, this transparent base being mixed with some suitable colouring matter. The base is produced by mixing its ingredients together by grinding them, then fusing the mixture and drying the fused base, which is again fused and again ground, when it is ready for use by being made into a paste with a little water. This paste is laid on the metal, and the metal put into the enamelling stove or oven to fuse and bake the enamel. The following is a typical mixture for the base of a transparent enamel:—

3 parts siliceous sand.
1 ,, chalk.
3 ,, calcined borax (or else three parts broken crystal glass).
¼ ,, nitrate of potash.
1 ,, diaphoretic antimony (well washed).

The French enamellers use an enamel which consists of:—

130 parts of flint glass;
20½ ,, of carbonate of soda;
12 ,, of boric acid;

fused together and afterwards ground to a fine powder.

The colours obtainable are most rich and varied, for although much indifferent enamelled metal work is to be seen, there is also much of extreme beauty.

JAPANS differ from enamel, inasmuch as they consist of a compound of resinous matter dissolved in spirits of wine (methylated spirit); and the art of applying these japans

consists in drying off the coating of japan so that the vehicle is dissolved and the solid residue left as a firm, adherent glossy coating on the surface to which it has been applied.

The preliminary operation in japanning consists in cleaning and drying the surface to be japanned. When of any other porous material, it is given, while warm, several coats of wood filler or whiting, mixed up with rather a thin glue size, and is, when this is hardened, rubbed down smooth with pumice-stone. It is then ready for the japan finish. As a rule, metals seldom require any spirit preparation, but receive the japan ground direct on the clean, dry surface.

In japanning, wood and similar substances require a much lower degree of heat, and usually a longer exposure in the oven, than metals; and further, a higher temperature may be advantageously employed when the japan is dark than when light in colour.

The oven is usually a room or large box of sheet metal, and must be kept perfectly free from dust, smoke or moisture. The temperature is usually between 250° and 300° Fahr., at which it is found that the whole of the solvent or vehicle of the gum in the varnish is soon driven off, and the gummy residue becomes liquefied or semi-liquefied, in which state it adapts itself to all inequalities, and, if the coating is thick enough, presents a uniform glossy surface, which it retains in cooling.

The coloured ground is put on first and dried in the oven. Then several coats of varnish are successively put on and dried, and the whole rubbed down to a smooth surface with fine French chalk, a little oil being finally used to clear off the powder and give the work a brighter hue.

GILDING.

Gilding, though it can be performed by using one or other of the various metallic paints upon the market, is more properly done by laying thin sheet gold upon a surface

previously treated with japanners' gold size, and afterwards preferably treating it with several coats of varnish.

The following is one of many recipes for Japanners' Gold Size, given by Mr. H. C. Standage:

"Boil one gallon of linseed oil for two hours in a vessel capable of holding twice or thrice the quantity, then gradually stir in

11 ozs. red lead } dry.
11 „ litharge }
5 „ sulphate of copper crushed to powder.

"Keep the oil hot and stir up well from the bottom while adding these ingredients. Then continue the boiling until the oil has been boiled about three hours and add 2 lbs. of gum animé (previously fused and mixed with $3\frac{1}{2}$ pints of hot raw oil), and continue the heating and stirring for five hours, or until the mass hangs in strings from the ladle, yet drops in lumps; then allow the mass to cool somewhat, and mix with it 3 gallons of turpentine, having raked out the fire so that the vapour given off does not catch alight. Well mix, when the gold size will be ready for use and should dry in 15 minutes or less, under favourable conditions. It improves on drying."

The gold leaf used is classed as singles, doubles or trebles according to its thickness, and sold in books each containing 25 sheets, measuring $3\frac{1}{4}$ ins. square. It is obtainable in several different shades, varying from deep orange red down to a pale silvery hue—what is known as "Pale Gold Leaf" being an alloy of silver and gold.

Foreign gold leaf is thinner than the English, and the leaves are smaller. Dutch gold is copper leaf converted into brass and so coloured yellow by exposure to the fumes of molten zinc. It is cheap, and consequently is at times employed to cover large surfaces, but unless protected by varnish, it discolours.

WHITEWASH consists of pure white lime mixed with

water, and is frequently used for common walls and ceilings, though it does not adhere well to smooth surfaces, and comes off when rubbed or exposed to rain ; but it is cheap, cleanly and easily applied. The process of its application is generally known as lime-whiting.

The wash is improved by adding 1 lb. of tallow (free from salt), to every bushel of lime.

The following is a method of making an adhesive whitewash for external use :—

"Take a clean water-tight barrel, and put into it half a bushel of lime. Slake it by pouring water over it boiling hot, and in sufficient quantity to cover it 5 ins. deep, and stir it briskly till thoroughly slaked. When the slaking has been effected, dissolve it in water, and add 2 lbs. sulphate of zinc, and 1 lb. of common salt; these will cause the wash to harden, and prevent its cracking."

COMMON COLOURING is prepared by adding earthy pigments to the mixtures used for lime-whiting.

The following proportions may be used per bushel of lime, more or less, according to the tint required :—

Cream Colour—4 to 6 lbs. of ochre.

Fawn Colour—6 to 8 lbs. umber ; 2 lbs. Indian red ; 2 lbs. lampblack.

Buff or Stone Colour—6 to 8 lbs. raw umber, and 3 or 4 lbs. lampblack.

WHITE DISTEMPER is a mixture of whiting and size. The best way to prepare it is to soak 6 lbs. of whiting in soft water for several hours, pour off the surplus water, stir the whiting into a smooth paste, strain and add a quart of size in the form of a stiff jelly. Mix carefully so as not to break the lumps of jelly, melt in a water jacket, strain through muslin, leave in a cool place for the whole to take the form of jelly, and dilute with water for use.

The size should be used in the cold jelly form, else a rough surface will result.

Potato starch may be used in place of size if a very clean bright white is required.

COLOURED DISTEMPER is made by adding pigments to the whiting previously to introducing the size.

WATER PAINTS, made by many firms of repute under fancy names, have now largely replaced coloured distempers in general use. The best known of these are "Duresco," "Olsina," "Muraline," "Magnite," Hall's "Washable Distemper," "Calcitine," and Blundell's "Stucco Paint." For most of these it is claimed that they are free from whiting, and from the sanitarily objectionable ingredient of size—that they are readily applied, needing only to be mixed with water—and that, once dry, they will withstand the application of soap and water to a moderate extent. They require, however, to be applied exactly according to the directions supplied by their makers, and when this is done, all are equally satisfactory.

One of these, known as "Washite," is said to be fire resisting and weather-proof.

Chapter XLIII.

GLASS.

GLASS is a brittle transparent or translucent compound formed by fusion at a high temperature of silica (silicic acid) with one or more basic substances, one of which must be an alkaline metal—another well-known definition (Dumas) being that glass is a silicate of at least two metals of different groups, one of which must be an alkaline metal.

Thus, the essential substances are :—

1. Silica as the acid element;
2. Soda or potash as the alkaline base; and
3. Lime and oxide of lead as alkaline earths.

Transparent glass can be made of combinations of the following bodies :—

Acid.	Alkaline.	Earthy.	
		Colourless.	Coloured.
Silica Boracic Acid	Oxides of— Potassium and Sodium	Oxides of— Calcium Lead Barium Strontium Magnesium Aluminium Zinc Thalium	Oxides of— Iron Manganese Copper Chromium Uranium Cobalt Gold

Glass is not easily affected by water or ordinary solvents but is readily attacked by hydrofluoric acid, HF; and slowly dissolves in hot water if the immersion is prolonged, and in

damp air over a protracted period of time ; thus accounting for the peculiar cloudy and obscured effect of much old glass, and for the beautiful effects of iridescent scaling. It is a bad conductor both of heat and electricity.

While it will be noticed that the number of possible combinations is very great, for colourless glass it is essential that no iron impurities be present, either in the sand or lime. The best sand is obtained from Alum Bay (Isle of Wight), Leighton Buzzard, Lynn, and from certain localities in France and Belgium ; the lime used is calcined chalk, and the potash is obtained from Prussia and Galicia. Potash glass is free from the sea-green tinge present in the most brilliant soda glass, and the presence of red-lead ($2PbO, PbO_2$) is characteristic of flint-glass.

Whatever the constituents, about one-third of the whole charge is always composed of waste and broken glass, known as "cullet."

Window glass may be either "crown," "sheet," or "plate,"

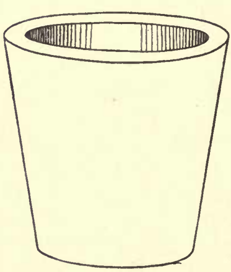


Fig. 177. Ordinary Glass Pot.

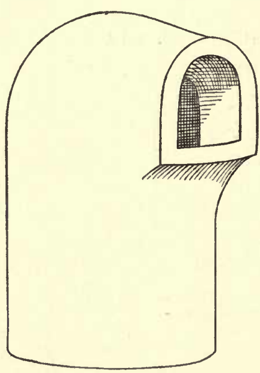


Fig. 178. Flint-Glass Pot.

according to the method of manufacture, crown glass being made by rotation, varying in thickness in the same sheet, and showing circular markings ; sheet glass being made in

even thicknesses of known weight of so many ounces per square foot, the better qualities perfectly flat with few bubbles, and the lower qualities with a wavy surface distorting objects seen through it, and containing long, narrow bubbles; and plate glass being made by casting, in thicknesses known by fractions of an inch, perfectly flat, and with few globular bubbles.

CROWN GLASS—generally flint-glass—is now little made, and need not be described in detail.

SHEET GLASS, while varying much in composition, may be considered to typically consist of:—

Sand (purified)	...	100 parts.
Chalk or limestone	... 35 to 40	„
Sulphate of soda	... 40 to 45	„
Cullet	... 50 to 100	„

These substances are mixed together, and put into large fireclay pots (see Figs. 177 and 178), containing from 20 to 22 cwts. each, which are ranged along the sides of furnaces (see Fig. 179), each pot opposite an opening, with platforms or stages radiating from the openings, and raised some 7 ft. above the bottom of a pit, that the blower, standing on the platform, may have a space below him in which to swing his blow-pipe. At the extremity of each platform farthest from the furnace is a water bucket and a moulding block.

The contents of the pots take sixteen hours to heat, and eight hours more to cool to working consistency.

When the right temperature is attained, a workman standing on each platform takes a blow-pipe (see Fig. 180), 6 ft. or 7 ft. long, dips its end into the pot opposite to him so as to gather on it a lump weighing about $1\frac{1}{2}$ lbs., and then cools this by swinging it in the pit; redips and gathers more; and so on till he has a lump of hot glass weighing about 20 lbs. on the end of his pipe. This he places in a horizontal position in his hollowed wooden moulding block (Fig. 181) and revolves while water is poured on; and then, when it is sufficiently formed and cooled, he blows down

the blow-pipe, still revolving the glass in the block, until a hollowed globe is formed (as in Fig. 182). This is re-heated and swung overhead, re-heated and swung again, until it is lengthened to a cylinder 45 ins. in length and 11 ins. to 16 ins. diameter, closed at one end, and with the blow-pipe at the other (Fig. 183). The open end of the blow-pipe is now

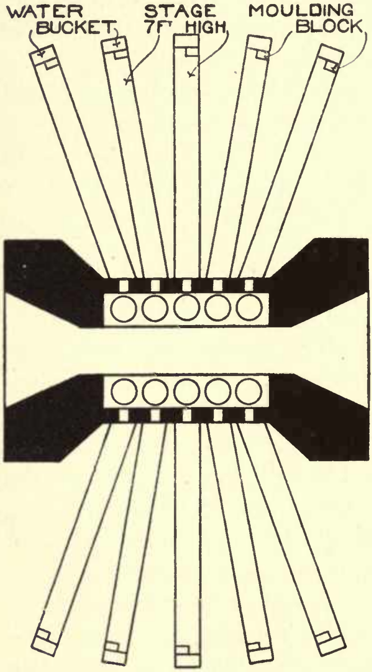


Fig. 179. Glass Furnace for 10 Pots.

Fig. 180. Blow-pipe.

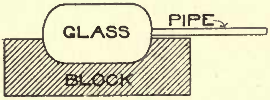


Fig. 181. Moulding Block.

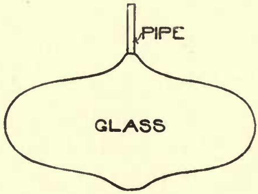


Fig. 182.

closed with the finger, the further closed end of the cylinder being directed towards the fire, softening the glass and expanding the enclosed air, with the result that the softened end opens. It is now rotated rapidly while presented to the fire, and flashes out perfectly straight, as shown (in Fig. 184). The top, next the blow-pipe, is now cut off, and the cylinder (or "muff") which is thus formed

is allowed to cool, and is then cut from end to end. This is put on the stone floor of a flattening oven with the split side upwards, and gradually heated, when it opens out by itself to a flat sheet, in which state it is inserted on edge in an annealing oven to cool down gradually.

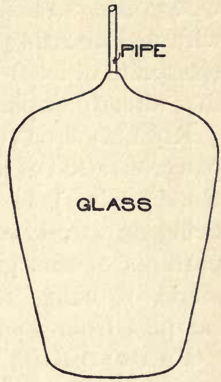


Fig. 183.

POLISHED SHEET or PATENT PLATE GLASS is made by polishing sheet glass in the way presently to be described, and is quite distinct from true plate glass.

Fig. 184.

PLATE GLASS is made of the purest materials, and with the greatest care to avoid bubbles, the following being a typical mixture :—

White quartzose sand ...	100	parts.
Soda carbonate	33·3	"
Slaked lime	14·3	"
Manganese peroxide ...	0·15	"
Cullet	100	"

The melting pots are large, containing as much as $2\frac{1}{2}$ tons of the mixture, which, when molten, is poured on to a table, and a roller passed over it to determine its thickness. The sheet of "rough plate" thus formed is taken to an annealing oven and gradually cooled, usually horizontally, and then examined for flaws, and cut to the largest size possible. It is then cemented with plaster of Paris on a table, which itself revolves horizontally under horizontal rubbers, being first *ground* with fine sand and water; then *smoothed* with emery, starting

with coarse and ending with fine grains; and finally *polished* with reciprocating rubbers having felt pads fed with rouge (peroxide of iron)—the whole process being very similar to that already explained for polishing marble.

ROLLED PLATE, either with plain grooves or with patterns raised or indented on the surface (known as Figured Rolled Glass), is made by the bed of the casting table being negatively enriched; and many exceedingly beautiful patterns of this glass, both clear white and coloured, are made, it being worth while, when selecting, to obtain samples from some well-known maker.

FIGURED ROLLED GLASS, as manufactured by Messrs. Chance & Co., of Birmingham, is made by rolling glass between two rollers instead of by a roller running on a table. The pattern is imprinted by a third (engraved) roller brought to bear upon the sheet of hot glass as it leaves the pair of rollers that determine its thickness. Many patterns are made, and the result is highly ornamental.

OBSCURED GLASS is generally obtained by subjecting ordinary clear glass to a sand blast.

Of COLOURED GLASS there are two kinds:—*Pot Metal*, which is uniformly coloured throughout; and *Flashed Glass*, which is ordinary transparent glass covered with a thin film of colour, by the blower dipping first into a pot of clear metal, then into one of colour, and so on.

The colours used are metallic oxides, varying in proportion and in the temperature used, and in most instances are trade secrets; but the following are known:—

Blue	Cobalt. (N.B.—Smalt is a powdered cobalt glass.)	Ruby...	Cuprous oxide.
		Brownish red ...	Iron oxide.
		Emerald green ...	Oxide of chromium.
Violet	Black oxide of manganese.	Dull yellow... ...	Powdered charcoal.
Black	Do. and cobalt.	Fine shades of yellow	Salts of silver or oxide of antimony
Purple of Cassius (range of ruby, carmine, and pink)	Gold with tin oxide.	Opalescent yellow	Uranium.

ENAMEL GLASS (opaque) is made by including lead and tin oxides calcined together, a typical mixture being :—

Sand	100 parts.
Pure potash...	80 „
Mixed oxides	200 „

This can obviously be made of many colours, and of it are formed the glass wall tiles, known as Uralite, Opalite, Crystallite, Newellite, etc., now largely used for lining such places as public conveniences, butchers' and fishmongers' shops, bath-rooms, etc. These vary from one another in little save the backing, which should preferably be of some substance, such as a bituminous compound, which will allow the glass to expand and contract under changes of temperature, as otherwise unsightly cracks are sure to occur.

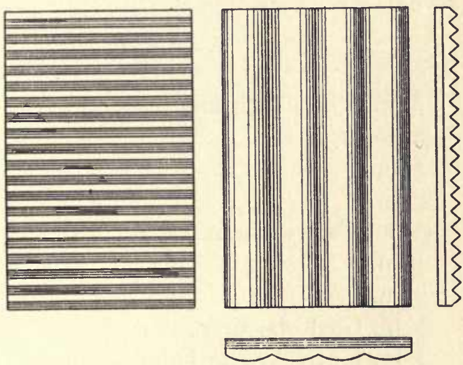


Fig. 185. Maximum Light Glass.

WIRED GLASS is a thick glass with wire netting embedded in it, used in positions where shocks and blows are to be expected. It has proved to be highly fire resisting.

The "MAXIMUM LIGHT GLASS" is a combination of prisms and lenses used as a substitute for window, plate or stained glass, said to increase the light from 5 to 20 times. It consists of carefully arranged lenticular surfaces running in vertical direction on the outside and at right angles to prismatic projections on the inside, and is manufactured in various size sheets and angles to suit all existing conditions (see Fig. 185).

The following particulars of the market sizes and thicknesses of different kinds of glass, supplied by Messrs. Chance Bros. & Co., Limited, of Birmingham, may be useful —it being noted that first and second quality *sheet glass* is not used for building purposes, the highest quality in use being thirds, while fourths and fifths (mostly Belgian) are commonly used :—

Sheet Glass.—16 oz., 21 oz., 26 oz., 32 oz., 36 oz., 42 oz.; 16 oz. Obscured—this is made in all thicknesses up to 42 oz.; 16 oz. Fluted—this is made also in 21 oz. and 26 oz.

Rolled Plate.

	Made in sizes up to
$\frac{1}{8}$ in. Plain with fine lines.	120 ins. long × 40 ins. wide.
$\frac{3}{16}$ in. ,, ,, ,,	120 ,, × 42 ,,
$\frac{1}{4}$ in. ,, ,, ,,	120 ,, × 42 ,,
$\frac{3}{8}$ in. ,, ,, ,,	120 ,, × 42 ,,
$\frac{3}{16}$ in. Cast without lines	120 ,, × 42 ,,
$\frac{1}{4}$ in. ,, ,, ,,	120 ,, × 46 ,,
$\frac{3}{8}$ in. ,, ,, ,,	120 ,, × 46 ,,
$\frac{1}{4}$ in. Cast obscured.	
$\frac{1}{4}$ in. Extra White Double Rolled Cast.	

Figured Rolled—*White—Tinted.*—Up to about 90 ins. long and 36 ins. wide.

Double Rolled Cathedral—*White—Tinted.*—Up to about 90 ins. long and 28 ins. wide.

Ordinary Rolled Cathedral—*White—Tinted.*—Up to about 90 ins. long and 28 ins. wide.

Muffled—*White—Tinted—Ruby.*—Blown glass, and made in only one thickness (about 18 oz.) and in sizes up to 42 ins. × 33 ins., or for *White* 50 ins. × 36 ins. Usually only required in small and moderate sizes, for which it is most suitable.

Crown.—Supplied now in only one thickness (13 oz.) and unselected in quality. It should not be ordered for sizes above 16 ins. × 12 ins. at outside.

Patent Plate.—This is blown glass ground and polished.

Coloured.

Signal Green (16 oz.)—*Flashed Ruby* (16 oz.).—Made also in 21 oz. and 26 oz., and chiefly used for railway signals.

Flashed Blue (16 oz.).—Made also in 21 oz. This as well as flashed ruby to a certain extent used for embossing.

Fluted Ruby (16 oz.).—For lead-light work.

Sanded Ruby (16 oz.).—For lead-light work and made also in 21 oz.

Sheet Cathedral Warm Tint (16 oz.)—*Cold Tint* (16 oz.)—*Sanded Warm Tint* (16 oz.)—*Sanded Cold Tint* (16 oz.).—For lead-light work; made also in 21 oz.

Chapter XLIV.

WALL AND CEILING PAPERS—STAMPED LININGS — FABRIC LININGS — METAL LININGS.

THE PAPERS used for covering walls and ceilings are of several different descriptions, known by different names, which sometimes denote the character of the paper itself and sometimes the printing process employed.

The commonest description of paper used is that known as *Pulp Paper.* It is thin, and is coloured throughout its substance, this colour being utilised as the ground of the design afterwards printed on it—for it is very rarely used unprinted, except the white, and that only as a lining paper.

Ingrain Papers also have the colour penetrating the substance. They are stout papers with a slightly rough and woolly surface, strong and serviceable, and exceedingly uniform in tint. As a rule they are used plain, as general wall coverings (or "fillings," as these are technically called), but patterns, usually of a small and formal character in few tints, are occasionally printed on them. Their only objection is that the rough surface catches the dust, and they are consequently difficult to keep clean.

Eltonbury Silk Fibres and *Eltolines* are again self-toned papers, smooth on one side and slightly roughened on the other, but not woolly, made of good substance and in beautifully pure tints. Like Ingrain Papers, they are somewhat expensive, but are strong and lasting; and though generally used plain are occasionally printed.

Plain White Paper of good substance is, however, generally used, and is prepared for printing by coating one side of it with a coloured ground. This is done by passing it

round a roller fed with colour from a trough by means of a blanket. Directly after leaving the roller, it passes beneath a series of reciprocating brushes which distribute the colour evenly over the surface, and it is then carried from the machine on to a rack, where it is suspended in festoons by rods over steam pipes to dry. At the "Essex" Mills, where the process was inspected, the paper from the racks is wound off on to a large roller at one end, dry and ready for printing, as it is fed from the machine at the other end (see Fig. 186). Grounds of two or more tints in parallel strips can be printed by using several colour rollers side by

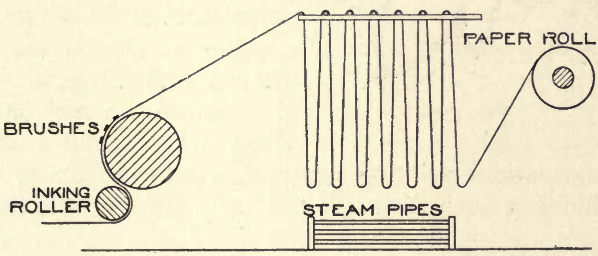


Fig. 186. Drying Rack.

side, the reciprocating brushes doing the work of gradual mergence of the tints.

Satin and *Satinette Papers* are made by brushing with powdered French chalk, or with a substance known as "satinette," on a dried coloured ground; and *Frosted Paper* by more lightly brushing over with mica.

Paper can be *embossed* by passing it between two steel rollers on each of which a pattern has been engraved, using considerable pressure; and this can be done either before or after printing.

Ordinary patterns with regular repeats are MACHINE PRINTED, all the various colours being applied at one operation. At Messrs. Essex & Co.'s mills, and doubtless at all other manufacturers', a separate wooden roller (see Fig. 187) is used for each tint, so much of the pattern as is

to be printed of that tint being formed upon the roller with copper lines and dots, or copper outlines filled with felt for the broader surfaces (see Fig. 188). The setting of this copper "type" is exceedingly difficult work, as the rollers must all be set that the pattern may fit; and obviously the circumference of the roller, outside the raised copper work, must be equal to the length of a repeat. In the printing machine, diagrammatically shown in Fig. 189, the paper is wound off a reel on to a large drum round which are set the various printing rollers, up to the capacity of the machine, at such distances that the patterns will exactly

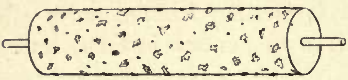


Fig. 187. Wooden Roller.

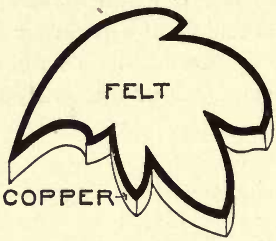


Fig. 188.

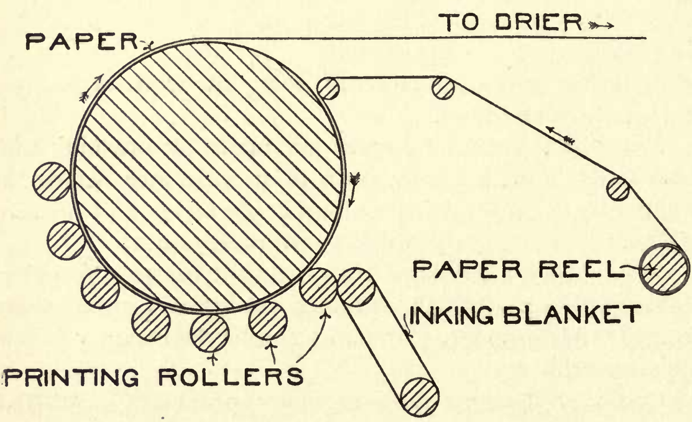


Fig. 189.

tally. As the drum revolves so do the rollers, each picking up colour from a moving inking blanket supplied from a

trough. Thus colour after colour is printed, each being applied while the previous ones are still wet, rendering super-imposition of colours impossible if blurred effects are to be avoided; and the paper passes off the drum completely finished, and is carried at once to drying festoons similar to those already described and shown in Fig. 186.

All the best papers are, however, either HAND PRINTED or STENCILLED. For hand printing, the pattern is left raised upon a flat pearwood board by cutting down the portions which are not to print, copper strips and dots only being used for exceptional and slender work. The flat boards are backed with other wood, and the slab thus formed can be of any convenient size. There is a handle at the back for lifting it by, and it is alternately pressed upon a felt blanket stretched over a dish of colour, and upon the paper, which is slipped along a table, a "repeat" at a time, exact connection being made by means of marks along the edges. Very large patterns necessitate the use of two or three blocks to each repeat, they being applied in sequence. Only one colour can be printed at a time. If a hand-printed paper has more than one tint in it, the process has to be repeated for each additional tint, after drying, super-imposition of colours thus being possible. Gradual blending of tone can, however, be managed, by having two colours on the felt, gradually worked into one another.

Stencilled papers are made by cutting a stencil pattern in sheet zinc, the colour being worked in through the stencil with stiff, short-bristle brushes held nearly vertically in the fist, and worked with a rotary motion. Graded effects can be produced by this method which are not possible by any other.

In all cases water-colours are used, but for machine printing these are necessarily thin and bound with gum, while for hand printing they are mixed with size and work as thick body-colour.

Sanitary Wall Papers form a distinct and highly important class. As made by Messrs. J. Line & Son, who

supply this information, they are of four classes, a specially prepared colour, water-proof and made with an oily medium, being used in each case, and the printing being done by machinery. One class is made by printing with this colour in the usual way with the usual rollers; but not much is made in this way. The best Sanitary Papers are printed from copper rollers on which the pattern is engraved instead of being raised, somewhat after the fashion of a mezzo-tint; and by means of lightly or more deeply engraving, many shades of colour can be obtained, only one roller being used. The pattern is thus printed on a surface already coated with the specially prepared colour, and the result is a smooth-surfaced paper which can be sponged. A third class of paper is made by callendering the paper instead of coating it with a coloured ground before printing, thus giving a smooth surface, which, however, will not stand washing unless great care be used; and the cheapest sanitary paper, printed from the roller direct on to unprepared paper, has not the same smooth surface, and can only by a stretch of courtesy be called either "sanitary" or "washable."

Flock and *Cork Papers* are made by printing the pattern in gum, and then beating flock or cork dust so that it adheres to the gummed surface, on which it appears as a rough raised surface. Such papers are distinctly handsome, but are rarely used as they catch dust with great readiness and cannot be kept clean.

Japanese Papers are hand printed in Japan on very thick paper, in handsome patterns which are generally embossed, the colouring being brilliant and gilding being freely used.

Lignomur is a thick embossed paper, almost a cardboard in substance, mostly used for ceilings, dadoes and friezes. It is made white only, but can be coloured or gilt in a variety of ways. Other very similar substances, some of them made in colour as well as white, are known as "Lincrusta Walton," "Anaglypta," "Tynecastle Canvas," and a variety of other names.

All English papers are made 21 ins. wide, with ½ in. margins, so that the actual width of the pattern is 20 ins. As a rule one margin is cut away for hanging, the other being overlapped; but in the best class of work both margins are carefully cut, and the edges are brought together. The paper is rolled in "pieces," each 12 yards long.

As the paper machines are made for the standard width, this also determines the depth of machine-printed friezes, which may be 10½ ins. or 7 ins. gross—the former technically known as a "two-over," and the latter as a "three-over" frieze, according to whether it is printed in two or three repeats on the width, and afterwards cut. Hand-printed friezes, however, are not subject to such strict limitations, and are obtainable of many other widths.

Fabricona is a name given to a fabric resembling coarse canvas made with a smooth back for use as a wall lining in several tints, and also with a surface similar to that of white duck. It makes a good background for pictures, and wears well.

METAL LININGS have also been introduced, and have at least the advantages of permanency and of requiring no underlying plaster. Of these, *Emdeca* is in thin enamelled sheets, slightly embossed, while *Steleonite* is of steel, much more richly embossed, and prepared for painting. Either can be screwed into position, while they are so thin that wire nails can be easily driven through them.

Chapter XLV.

SUNDRY MATERIALS OF LESSER IMPORTANCE: ASBESTOS—URALITE—SLAG-WOOL—EUBOLITH—LIGNOLITE—RUBEROID—LATHS—EXPANDED METAL—COMPO-BOARD—FELT—WILLESDEN PAPER—VULCANIZED RUBBER—THATCH—GLUE—SIZE—PASTE—RUST CEMENT—TAR.

ASBESTOS occurs as a natural rock of a fibrous nature, found in South Africa and Austria. The fibres are separated, and woven into cloth or powdered. It is probably the most highly fire-resisting material known, becoming incandescent under direct flame without burning to any appreciable extent, but at the same time capable of resisting and refusing to conduct even considerable temperatures. Consequently it is the basis of almost all non-conducting cloths and packings used round steam and other hot pipes, between iron fireplace fronts and wood mantels, and in other similar positions.

Asbestos slates have been introduced of recent years, mainly for use in hot climates, they being (in the compressed form) fire and water proof, and unaffected by extreme variations of temperature. They are much lighter in weight than ordinary slate, and can be cut, sawn, nailed and screwed, veneered, ground, and painted. They are supplied both compressed and uncompressed, but to make the uncompressed slabs damp-proof they must be well coated with a

thick boiled solution of soap. The following are the sizes made :—

COMPRESSED.

For Roofing, etc.

24 ins. × 12 ins. × $\frac{1}{8}$ in. 12 ins. × 12 ins. × $\frac{1}{8}$ in.
*16 ins. × 16 ins. × $\frac{1}{8}$ in. 12 ins. × 6 ins. × $\frac{1}{8}$ in.
16 ins. × 8 ins. × $\frac{1}{8}$ in.

* Weight, 4 tons per thousand of this size.

NON-COMPRESSED.

For Ceilings, Partitions, and Walls.

8 ft. × 4 ft. in thicknesses of $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{3}{8}$ in.
4 ft. × 4 ft. " " $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{3}{8}$ in.
2 ft. × 1 ft. " " $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{3}{8}$ in.

The shapes made are shown in Figs. 190 to 195.

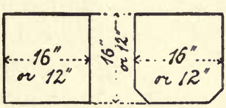


Fig. 190.

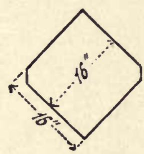


Fig. 191.

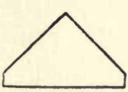


Fig. 192.
$\frac{2}{3}$ of a tile.

Fig. 193.
Eaves.

Fig. 194.

Fig. 195.

URALITE is similar to asbestos slates, made in sheets either plain or stamped with a pattern on the face, of asbestos fibre cemented by a mineral glue. It is intended to replace plaster upon ceilings and stud partitions, to which it can be screwed. It is made in thin slabs in two forms, hard and soft. The hard is used for roofs and other external work, ceilings, walls, partitions, doors, etc., and the soft for insulation, engineers' joints, and in the manufacture of fire-resisting doors.

SILICATE-COTTON, or SLAG-WOOL, possesses almost the same properties as asbestos, for which it is largely employed as a substitute, though it is also, and perhaps more, used as an exceedingly light sound-proof packing in which vermin will not live, and as the basis of various fire-resisting plasters. It is made by blowing a jet of steam through a small falling stream of molten slag, when it falls as a light open substance similar to cotton-wool, but more metallic in character.

EUBOLITH is a composition flooring, made partially of sawdust, which, like asphalt, can be laid without joint and is water - resisting. Whether it would wear evenly or last well would be matters for experience to decide. It is almost noiseless.

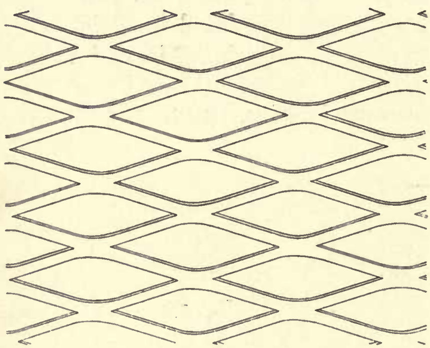


Fig. 196. Expanded Metal Lathing.

LIGNOLITE flooring is laid like cement, sets quickly and becomes very hard, and is not cold to the touch like stone. It is fire-resisting and impervious, is easily repaired, and can be laid on either concrete or wood.

RUBEROID is a high grade felt roofing, containing no tar, pitch, rubber or other short-lived ingredient. It is made in four thicknesses, known as "plies," viz., $\frac{1}{2}$, 1, 2 and 3-ply, of which the $\frac{1}{2}$-ply is thin and recommended for under-slating, while the 3-ply is very thick, for severe use and on roofs exposed to great heat and chemical action. It is also used for damp courses, and for flooring.

LATHS are thin strips of wood or metal, about 1 in. wide and 3 or 4 ft. long, of various thicknesses, used as a support for plastering upon timber joists or studs. They ought to

be split by hand from oak or fir heartwood, but the greater number now in use are sawn from fir sapwood by machinery. Plasterers' laths are classified as—

Single laths	$\frac{1}{8}$ to $\frac{3}{16}$ in. thick.
Lath-and-half laths	$\frac{1}{4}$ " "
Double laths	$\frac{1}{2}$ " "

Bundles generally contain 360 lineal ft., but sometimes more, up to 500 ft.

Slate or *Tiling Laths* (also known as *Battens*) are sawn out of larger stuff and sold in 10 ft. lengths, the width and thickness varying from $1\frac{1}{4}$ in. by $\frac{3}{4}$ in. to 2 ins. by 1 in. and 3 ins. by 1 in.

EXPANDED METAL (see Fig. 196) consists of mechanically-slit and opened-out sheets of metal, so as to produce trellis or net-like work, with diamond-shaped meshes and strands of, practically, any desired sizes and thicknesses. The cutting and opening out of the diagonal strands by the machine are effected in one operation. It is frequently used instead of lathing, as also are several other forms of cut metal sheets.

It is manufactured in sheets of almost any convenient size, but the limit the long way of the mesh is at present 16 ft.

The following sizes of mesh are made :—

Mesh.	Strands.	Mesh.	Strands.
6 in.	$\frac{1}{4}$ in. × $\frac{1}{4}$ in.	3 in.	$\frac{1}{4}$ in. × $\frac{1}{8}$ in.
6 in.	$\frac{3}{8}$ in. × $\frac{3}{16}$ in.	3 in.	$\frac{3}{16}$ in. × $\frac{1}{8}$ in.
6 in.	$\frac{1}{4}$ in. × $\frac{3}{16}$ in.	3 in.	$\frac{3}{16}$ in. × $\frac{3}{16}$ in.
6 in.	$\frac{1}{4}$ in. × $\frac{1}{8}$ in.	3 in.	$\frac{1}{8}$ in. × $\frac{1}{8}$ in.
6 in.	$\frac{3}{16}$ in. × $\frac{1}{8}$ in.	3 in.	$\frac{1}{4}$ in. × 16 G.
6 in.	$\frac{1}{8}$ in. × $\frac{1}{8}$ in.	$1\frac{1}{2}$ in.	$\frac{1}{4}$ in. × $\frac{3}{16}$ in.
3 in.	$\frac{1}{4}$ in. × $\frac{1}{4}$ in.	$1\frac{1}{2}$ in.	$\frac{1}{4}$ in. × $\frac{1}{8}$ in.
3 in.	$\frac{3}{8}$ in. × $\frac{3}{16}$ in.	$1\frac{1}{2}$ in.	$\frac{3}{16}$ in. × $\frac{1}{8}$ in.
3 in.	$\frac{1}{4}$ in. × $\frac{3}{16}$ in.	$1\frac{1}{2}$ in.	$\frac{1}{8}$ in. × $\frac{1}{8}$ in.

EXPANDED METAL (SIZES OF MESH)—*continued.*

Mesh.	Strands.	Mesh.	Strands.
$1\frac{1}{2}$ in.	$\frac{1}{4}$ in. × 16 G.	$\frac{3}{8}$ in.	$\frac{3}{32}$ in. × 18 G.
$1\frac{1}{2}$ in.	$\frac{3}{16}$ in. × 16 G.	$\frac{3}{8}$ in.	$\frac{3}{16}$ in. × 20 G.
$1\frac{1}{2}$ in.	$\frac{1}{8}$ in. × 16 G.	$\frac{3}{8}$ in.	$\frac{5}{32}$ in. × 20 G.
$1\frac{1}{2}$ in.	$\frac{3}{32}$ in. × 18 G.	$\frac{3}{8}$ in.	$\frac{1}{8}$ in. × 20 G.
$\frac{3}{4}$ in.	$\frac{3}{16}$ in. × $\frac{1}{8}$ in.	$\frac{3}{8}$ in.	$\frac{3}{32}$ in. × 20 G.
$\frac{3}{4}$ in.	$\frac{1}{8}$ in. × $\frac{1}{8}$ in.	$\frac{3}{8}$ in.	$\frac{3}{32}$ in. × 22 G.
$\frac{3}{4}$ in.	$\frac{1}{4}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{1}{4}$ in. × 16 G.
$\frac{3}{4}$ in.	$\frac{1}{8}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{3}{16}$ in. × 16 G.
$\frac{3}{4}$ in.	$\frac{3}{32}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{5}{32}$ in. × 16 G.
$\frac{3}{4}$ in.	$\frac{3}{32}$ in. × 18 G.	$\frac{1}{4}$ in.	$\frac{1}{8}$ in. × 16 G.
$\frac{3}{4}$ in.	$\frac{3}{32}$ in. × 20 G.	$\frac{1}{4}$ in.	$\frac{3}{32}$ in. × 16 G.
$\frac{3}{4}$ in.	$\frac{3}{32}$ in. × 24 G.	$\frac{1}{4}$ in.	$\frac{3}{16}$ in. × 18 G.
$\frac{3}{8}$ in.	$\frac{1}{4}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{5}{32}$ in. × 18 G.
$\frac{3}{8}$ in.	$\frac{3}{16}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{1}{8}$ in. × 18 G.
$\frac{3}{8}$ in.	$\frac{5}{32}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{3}{32}$ in. × 18 G.
$\frac{3}{8}$ in.	$\frac{1}{8}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{3}{16}$ in. × 20 G.
$\frac{3}{8}$ in.	$\frac{3}{32}$ in. × 16 G.	$\frac{1}{4}$ in.	$\frac{5}{32}$ in. × 20 G.
$\frac{3}{8}$ in.	$\frac{3}{16}$ in. × 18 G.	$\frac{1}{4}$ in.	$\frac{1}{8}$ in. × 20 G.
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$\frac{3}{8}$ in.	$\frac{1}{8}$ in. × 18 G.	$\frac{1}{4}$ in.	$\frac{3}{32}$ in. × 22 G.

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VENESTA is a similar sandwich, but of three thicknesses of wood only.

FELT is a substance made from hair or wool beaten into a more or less compact tangle. The following information respecting the forms in which it is used in building has been supplied by Messrs. Engert and Rolfe :—

Asphalted Roofing Felt.—A material manufactured for external roofing of sheds, barns, and other similar structures. When laid and covered with Coating Mastic a thorough and satisfactory job is secured, which will last, with very little attention, in good order for many years.

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Hair Bitumen. — This material is by a long way the best underlining felt. It is largely composed of hair, and is used extensively as a sound-deadener in connection with partition work, and under flooring as a pugging. (In the latter position the material should be carried on the tops of the joists over the whole of the flooring, and not cut into strips and placed on the top of and (*or*) between the joists only ; and this applies equally to all similar sound-deadening materials.) For sound-deadening purposes the material is made a trifle stouter than when it is required as underlining for roof covering. It is vermin-proof.

Hair Felt is a loose, dry substance, not impregnated with any other. It is manufactured in sheets and in continuous lengths. The uses of hair felt are various, but it is mainly adopted as a non-conductor for covering boilers, tanks, pipes, etc., and also in buildings as the seating for girders.

Canvas-backed Hair Felt.—Hair felt in strips in a

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Stonifex Roofing Felt, made by Messrs. Anderson & Son, Limited, does not contain coal-tar or pitch, but is rubber-like and densely compressed. When exposed on a roof it oxidizes, and is extremely lasting, especially if coated with mastic, a precaution which should be taken with all felts used externally. It is of a dense black colour.

WILLESDEN PAPER and CANVAS are often used in place of underfelting for roofs and for outside blinds and awnings. They are water-proof and rot-proof, made so by passing them through copper and ammonia (cuprium ammonium) in solution, the surface of the canvas being partially reduced to cellulose, and this again run back and pressed into the substance, thereby producing a semi-metallic surface highly impregnated with copper and ammonia. It is possible with this method of treating canvas to roll it up while still wet and put it away for an indefinite period without fear of mildew or rotting—a most valuable quality, especially for sun-blinds. Both paper and canvas are made in several thicknesses and qualities for different purposes, and of various widths up to 60 ins., in rolls which vary from 90 yards to 360 yards in length.

VULCANIZED RUBBER consists of indiarubber impregnated with sulphur. It is much used for valve seatings, and also as a packing to thick plate glass in place of putty. A rough way of testing its quality is to throw a piece into water. If it sinks it probably contains an injurious excess of sulphur.

THATCH is usually formed of thoroughly dry straw or reeds. According to Mr. J. G. Cowell, of Soham, the reeds used for thatching grow by the sides of large tracts of water, chiefly in the Eastern Counties. They are cut during the months of January and February after good

sharp frosts. It is usual to wait for the "flag," which grows on top of the reeds, to fall before cutting. The lengths are various; 4 ft. to 6 ft. lengths are the best for ornamental or rustic work, and for circular and short rafter buildings, 4 ft. to 6 ft. lengths are most suitable. Some grow 6 ft. to 9 ft., but these are very coarse and only fit for long rafter work. In some districts a large proportion of rushes, boulders, or gladdin grow amongst reeds. They make very good, sound roofing, but do not look quite so well as all reed on a roof. All are tied up 18 ins. from stub end in bunches, or sheaves. The size or girth of tie varies according to custom of grower, or locality. Reeds are usually sold at per hundred fathom of 600 bunches, but sometimes 720 bunches are called one hundred fathom, and others sell at per hundred (60 bunches).

Reeds should be laid in narrow rows to dry, or in small stacks, with a coat of thatch over, for the March and April winds to dry. They should be thoroughly well seasoned before being put on roofs, and over-year reeds are preferable, but very difficult to obtain.

Wheat-straw thatch will last from fifteen to twenty years, while reed thatch will last as long as sixty and even seventy years, if cleaned down and knocked up tight every five years.

GLUE is made from animal offal of all sorts, such as hoofs, horns, and skin, by steeping it in water, and then washing, boiling, straining and melting it—much as the stock for soup is made—and casting it into square cakes. The best is of a clear dark amber colour, free from spots or cloudy patches, and swells much when immersed in cold water, without dissolving; while inferior glue will dissolve. The strength is increased by adding powdered chalk, but it is then rendered fit for coarse work only.

SIZE is made by melting glue with heat in water, and then adding more water until it is thin enough for use—a pound of glue making about a gallon of size. Double size is merely size to which less water than usual has been added.

Clear Cole is another name for size; while *Parchment Size* is made by dissolving fine chopped parchment in warm water for the use of gilders—and is one of several varieties, all known as *Gold Size.*

PASTE is generally made from white wheat flour, by mixing it into a stiff batter with a little cold water, adding cold water while stirring so as to thin the batter, and then pouring absolutely boiling water over it, stirring all the time, till it swells and thickens—the process being exactly similar to that of making a cup of cocoa. The addition of alum ($\frac{1}{2}$ oz. of alum to every lb. of flour) just before the boiling water is added, makes the paste stronger, but more difficult to apply. Rosin and gum arabic are also sometimes added.

RUST CEMENT, used for forming joints in cast iron work, is made from pounded cast iron turnings to which powdered sal-ammoniac and flour of sulphur are added, the mixture being first damped till it begins to heat, and then well mixed and covered with water. The proportions vary between the following :—

	Quick Setting.	Slow Setting.	
C.I. turnings ...	200 ...	200	parts by weight.
Sal-ammoniac ...	$2\frac{1}{2}$ ...	2	„ „
Flour of sulphur ...	5 ...	1	„ „

TAR, which is a bye-product of the manufacture of gas, is obtained by heating coal in closed cylinders. From it are obtained, by distillation, in succession, coal naphtha, creosote and pitch.

Wood Tar, which is imported from the Baltic as Stockholm, and from the United States as American tar, is produced by distilling resinous wood; while *Mineral Tar* is found in Burmah or can be distilled from bituminous shales.

A new substance has lately been introduced which forms a cheap and serviceable plastic material for fancy mouldings,

cornices, pilasters, dados, skirting, &c. It consists of waste paper pulp—a refuse from paper mills—sawdust or inert material agglutinated by ALGIN. This latter substance is a kind of size obtained from seaweed and produced by the British Algin Company, Holywell, North Wales.

ALGIN is a jelly-like mass, of an alkaline nature and slightly adhesive. It is obtained from seaweed by the action of caustic soda.

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